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PRELIMINARY FISHERIES SURVEY OF THE HAWAIIAN-LINE ISLANDS AREA[1]

PART II - NOTES ON THE TUNA AND BAIT RESOURCES OF THE HAWAIIAN, LEEWARD, AND LINE ISLANDS[2]

By Fred C. June*

PREFACE

The present report is a digest of the miscellaneous information gathered on the tunas[3] and tuna bait-fish resources of the Hawaiian, Leeward, and Line islands; together with related information on the physical characteristics of the various land masses and surrounding seas. The data have been assembled from available literature, discussions with fishermen, and field observations made at various islands in the region. In many instances, desired data could not be obtained without additional field work, which conditions did not permit. However, it is hoped that this summary will be of some aid to those interested in commercial tuna fishing in these waters.

TABLE OF CONTENTS

	PAGE		PAGE
THE HAWAIIAN ISLANDS:	1	THE LINE ISLANDS:	15
INTRODUCTION	1	INTRODUCTION	15
SEA TEMPERATURES	2	SEA CONDITIONS	15
OCEAN CURRENTS	3	BAIT RESOURCES	16
WATER DEPTHS	6	TUNA RESOURCES	18
TUNA AND BAIT RESOURCES	6	CANTON ISLAND:	20
LEEWARD ISLANDS:	9	INTRODUCTION	20
INTRODUCTION	9	SEA CONDITIONS	21
SEA CONDITIONS	9	BAIT RESOURCES	21
BAIT RESOURCES	9	TUNA RESOURCES	21
TUNA RESOURCES	14	LITERATURE CITED	22

THE HAWAIIAN ISLANDS

INTRODUCTION: The Hawaiian Islands proper consist of eight major islands: Hawaii, Maui, Molokai, Kahoolawe, Oahu, Kauai, and Niihau; comprising a total land area of approximately 6,450 square miles, of which the island of Hawaii comprises about 62 percent. The islands are all mountainous and of volcanic origin. Their coastlines are indented by numerous bays and coves, and in many places long stretches of white sand beaches, alternating with rocky shores and headlands, rise from the shallow waters inside the reefs. At other places there are no beaches at all; the steep cliffs often drop directly into deep water, or their bases are strewn with

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1/PART I - THE HAWAIIAN LONG-LINE FISHERY BY THE SAME AUTHOR APPEARED IN COMMERCIAL FISHERIES REVIEW, JANUARY 1950, PP. 1-23; ALSO AVAILABLE AS SEPARATE NO. 244.

2/DR. SIDNEY SHAPIRO, FISHERY RESEARCH BIOLOGIST, U. S. FISH AND WILDLIFE SERVICE, COLLABORATED IN THE PRELIMINARY PHASES OF THIS INVESTIGATION.

3/THE VARIOUS TUNA SPECIES CONSIDERED HERE INCLUDE: YELLOWFIN TUNA (NEOTHUNNUS MACROPTERUS), BIG-EYED TUNA (PARATHUNNUS SIBI), ALBACORE (THUNNUS GERMO), OCEANIC SKIPJACK (KATSUWONUS PELAMIS), AND "KAWAKAWA" (EUTHYNNUS YAITO).

lava rocks. In general, the fringing reef extends only a few hundred yards from shore.

Climate is fairly uniform through the year. Mean monthly air temperature at Honolulu varies from 71° F. in January to 78.4° F. in August. Northeast trade winds prevail throughout the year, but from October to April they are occasionally interrupted by "Kona" (southerly or southwesterly) winds. "Kona" weather is often accompanied by rainstorms which may last from a few hours to three or four days.

SEA TEMPERATURES: The average annual sea-surface temperature in the Hawaiian area is about 77° F. Maximum and minimum monthly averages are shown in table 1. It is at once apparent that, at the surface, the differences between the monthly maximum and minimum temperatures become smaller during the summer season and larger during the winter. The same condition exists at a depth of 100 feet, while at 200 and 300 feet, the differences appear to remain relatively constant. The horizontal distribution of sea temperatures at the surface, 100 feet, 200 feet, and 300 feet, at the two extremes of the year (February and August), is shown in figure 1. The thermocline, therefore, generally lies between 250 and 300 feet during the winter months, rising to roughly 150 feet during the summer (figure 2).

Table 1 - Maximum and Minimum Monthly Average Sea Temperatures (°F.) in the Hawaiian Area[1/]

Month	Sea Temperature							
	Maximum				Minimum			
		Feet				Feet		
	Surface	100	200	300	Surface	100	200	300
January	80	79	78	78	68	68	66	64
February ...	79	78	78	77	67	66	65	64
March	78	77	77	76	66	67	64	64
April	78	77	77	76	68	68	64	64
May	79	78	78	77	70	69	66	64
June	80	80	79	77	74	71	68	64
July	82	80	80	78	76	73	66	64
August	82	81	81	79	77	75	68	66
September ..	82	82	81	80	77	76	67	67
October	82	82	82	80	76	75	68	66
November ...	82	81	81	80	72	72	68	67
December ...	80	80	80	79	70	70	67	66

1/Reproduced from Oceanographic Rept. No. 12, June 1948, Scripps Inst. of Oceanography, Univ. of Calif.

Since the tunas are primarily warm-water forms, it is to be expected that the vertical and horizontal distribution of the various species is to some extent governed by sea temperature conditions. The results of the Japanese exploratory investigations in the region of the Inner South Seas, for example, indicate that sea temperature had a close bearing on the occurrence of skipjack and yellowfin tuna, especially in the region of the equatorial countercurrent, where the main fishing grounds for these species were located. Their findings indicate that when temperatures in this zone were below normal, a marked decrease in the catches of skipjack and yellowfin tuna occurred, followed by an increase in the long-line catches of big-eyed tuna and albacore.

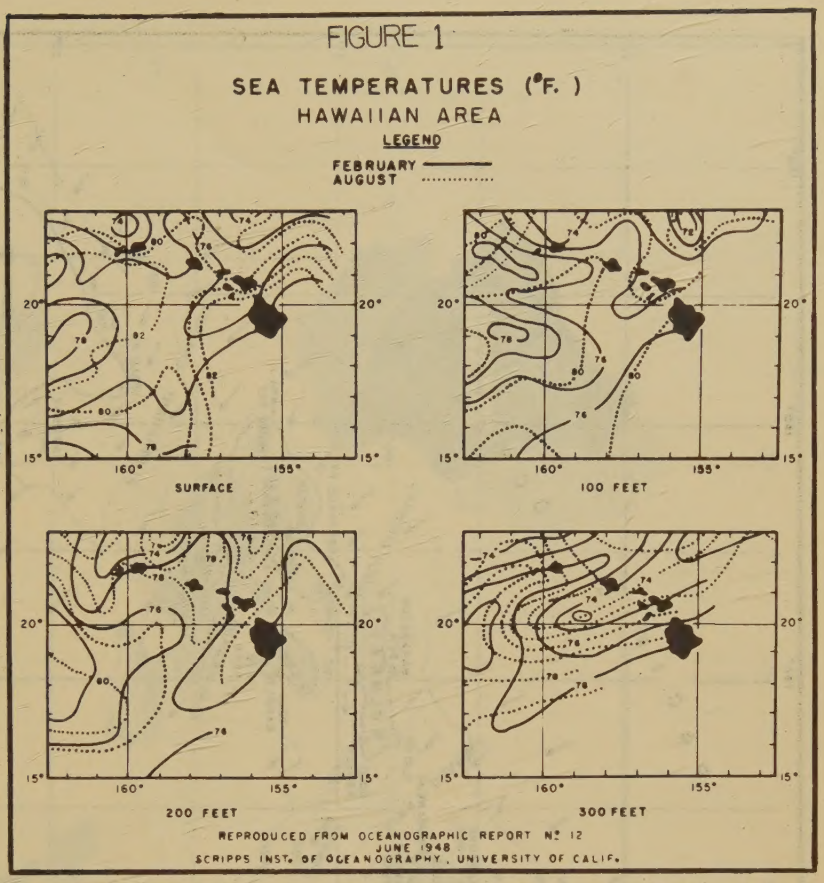
Although no basic studies on the relation of sea temperatures to the occurrence and abundance of tunas in Hawaiian waters have been completed, the Territorial Division of Fish and Game has been gathering data on the relation of subsurface temperatures to tuna long-line fishing. The commercial catch records indicate a marked increase in the landings of yellowfin tuna and skipjack, as the waters in this region become progressively warmer during the summer months. As the season advances and the waters again become cooler, the numbers of these two species entering the commercial catches show a decided decline. Big-eyed tuna and albacore, which may be less tolerant of the higher summer temperatures, occur in the catches in fewer

numbers during the summer season. These two species enter the catches in the greatest abundance during the winter months, and their increased appearance follows closely the decline of the yellowfin and skipjack.

OCEAN CURRENTS: The waters surrounding the Hawaiian Islands are subject to strong and variable currents through the year (figure 3). In general, currents run southwesterly and westerly offshore, due to the influence of the northeast trade winds. Close inshore, however, the flow is northward along the coastlines, except off the Puna (southeast) coast of Hawaii, where the inshore current flows in a southwesterly direction. In the channels between the islands, the currents are tidal, but to some extent, are influenced by the prevailing winds and the position of the islands with respect to each other.

FIGURE 1

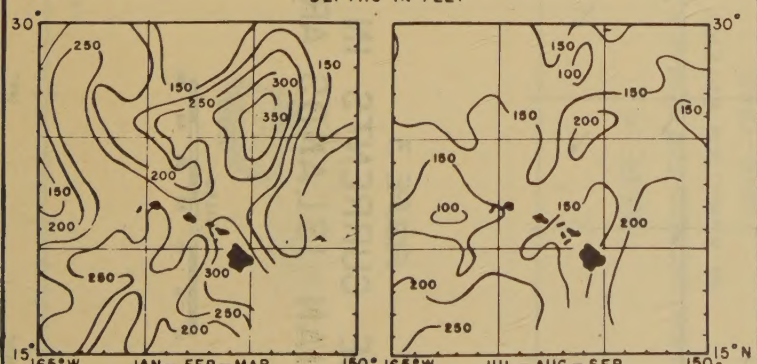
SEA TEMPERATURES (°F.)
HAWAIIAN AREA



REPRODUCED FROM OCEANOGRAPHIC REPORT Nº 12
JUNE 1948
SCRIPPS INST. OF OCEANOGRAPHY, UNIVERSITY OF CALIF.

FIGURE 2

AVERAGE THERMOCLINE DEPTH
HAWAIIAN AREA
DEPTHS IN FEET



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In Kauai Channel, the main current approaches from the northeast, but abruptly changes its direction of flow to the northwest as it strikes the shallow water bank that extends northwestward off Kaena Point, Oahu. It continues northwestward until it reaches the east coast of Kauai; here it divides in the vicinity of Nawiliwili Bay. North of the bay it follows the coastline and joins the main current north of the island. South of Nawiliwili Bay it joins a large eddy movement that exists south and west of Kauai. This eddy rotates in a clockwise pattern, extending a maximum of about 30 miles offshore. The north-

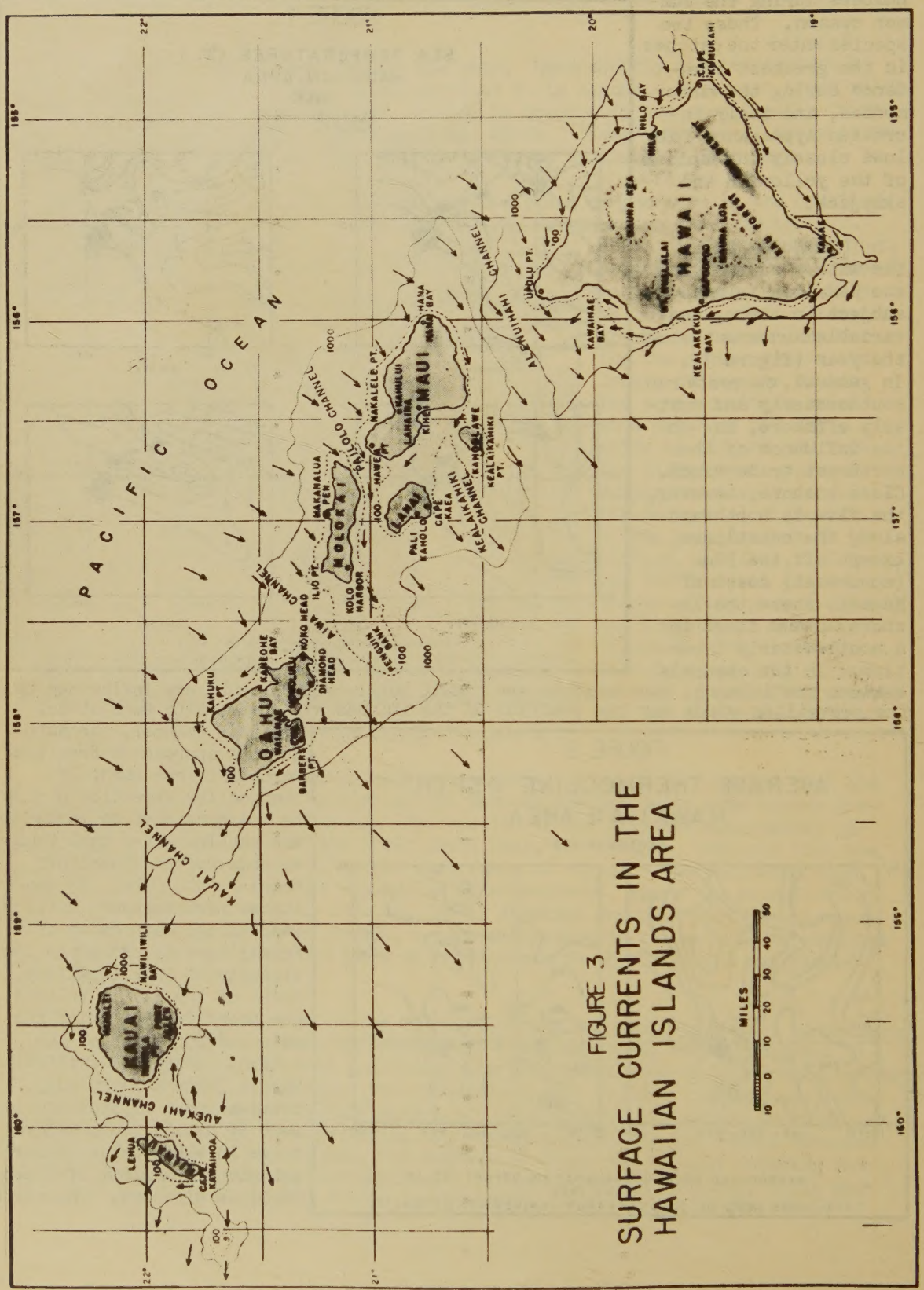


FIGURE 3
SURFACE CURRENTS IN THE HAWAIIAN ISLANDS AREA

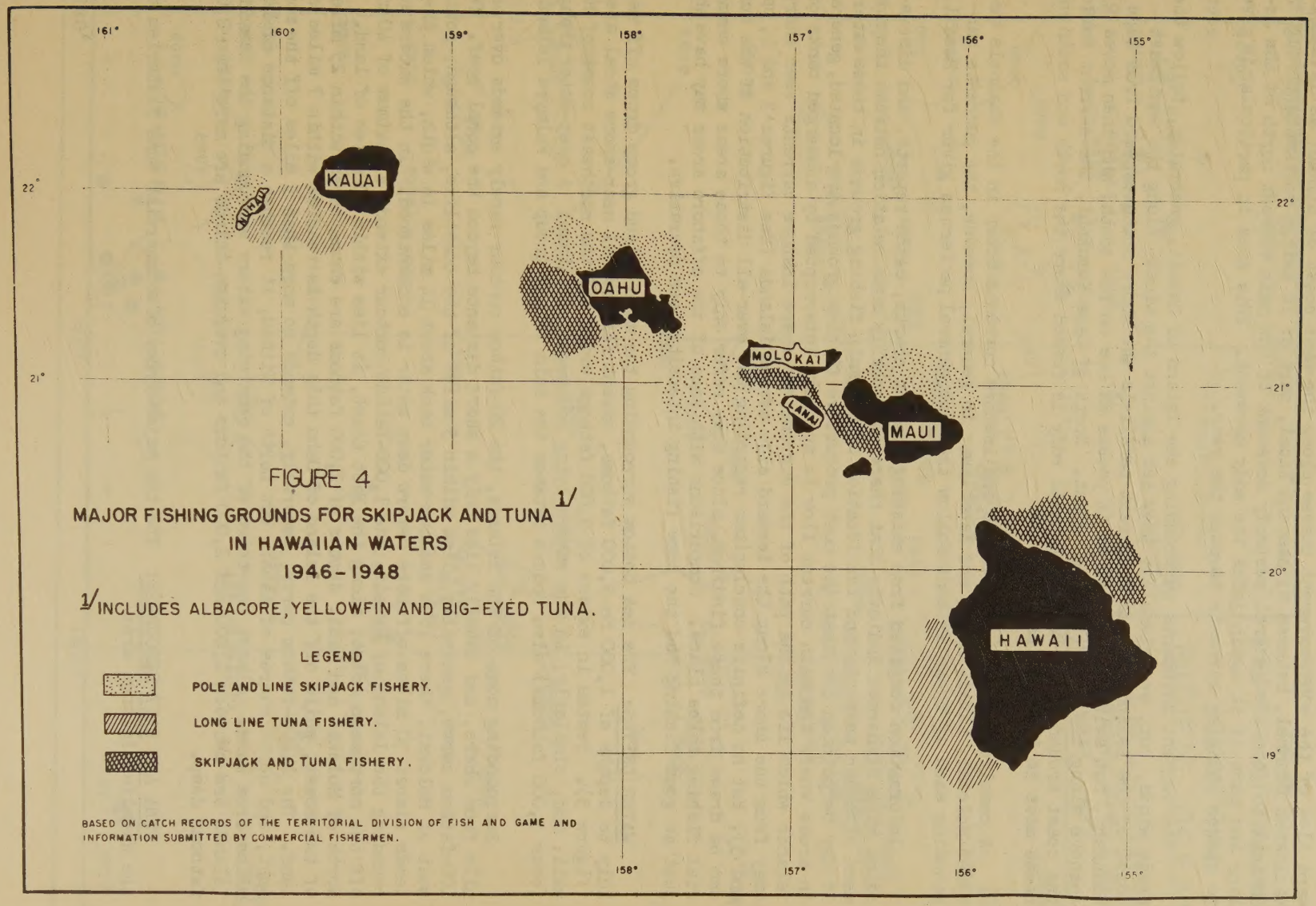


FIGURE 4

MAJOR FISHING GROUNDS FOR SKIPJACK AND TUNA 1/
IN HAWAIIAN WATERS
1946-1948

1/ INCLUDES ALBACORE, YELLOWFIN AND BIG-EYED TUNA.

LEGEND

- POLE AND LINE SKIPJACK FISHERY.
- LONG LINE TUNA FISHERY.
- SKIPJACK AND TUNA FISHERY.

BASED ON CATCH RECORDS OF THE TERRITORIAL DIVISION OF FISH AND GAME AND INFORMATION SUBMITTED BY COMMERCIAL FISHERMEN.

ward flow of the eddy movement passes along the east coast of Niihau; as it reaches Kaulakaha Channel, between Niihau and Kauai, part of it swings northward through the Channel to join the general westerly movement of the main current north of the Island and part of it again joins the eddy movement. This area in particular is given to sudden changing currents through the year.

The current movements surrounding the Island of Hawaii, generally, follow the trade winds, but, occasionally, they set against the wind. Along the southeast coast of the Island, the main current parallels the shore southwestward from Cape Kumukahi, but swings northwest as it passes Ka Lae on the south, and then moves close inshore along the Kona (leeward) coast. North of Cape Kumukahi, the current follows the coast around Upolu Point. A small eddy is formed where the north and south currents meet in Kawaihae Bay.

A complicated system of eddies and inshore currents occur in the channels between Molokai, Lanai, Maui, and Kahoolawe; in general, however, the currents surrounding each of these islands follow the same general patternas given for Hawaii.

Information compiled from existing current charts, catch reports, and discussions with fishermen indicate that there is probably some relation between the movement of ocean currents and the location of the main fishing grounds in these waters. It may be pointed out that the most productive fishing grounds are located, generally, in areas where the main current flow is abruptly interrupted by submerged banks or islands which lie in the path of the current, or where inshore currents veer sharply away from the shore along the leeward side of the islands (See figures 3 and 4, pp. 4 and 5), but no definite conclusions regarding the over-all distribution of the tunas can be drawn from these findings, since they refer only to those areas where commercial fishing takes place. Comparisons with some of the offshore areas may have shown just as good fishing had the same fishing intensity been operative.

WATER DEPTHS: The sea bottom surrounding the main island group drops off rapidly to depths of 1,000 to 3,000 fathoms, except for several near-shore shoal areas (figure 5). Depths in excess of 3,000 fathoms exist off the northeast coast of Hawaii, and, similarly, in the waters lying southwest of Niihau. A deep-water trough (over 3,000 fathoms) also occurs between the main island group and Palmyra Island.

Surrounding most of the islands, the 20-fathom contour rarely extends over one mile from shore, and usually lies only a short distance beyond the coral reef. The 100-fathom curve, generally, lies within 5 miles of the coastline, although, southwest of Molokai, there is a shallow-water bank about 14 miles in width, which extends almost 30 miles offshore before deep water is encountered. In the waters surrounding the Island of Hawaii, the 1,000-fathom contour extends a maximum of 40 miles off the northwest coast; along the East Coast, it lies within 10 miles of land. North of Molokai and Maui, depths of 1,000 fathoms are encountered within 25 miles of the coast, while off the island of Oahu this depth is reached within 7 miles of land. The 1,000-fathom curve, generally, extends no more than 5 miles off the south, east, and north shores of Kauai, but north of Niihau, it reaches a distance of 14 miles from land. Almost one-third of the remaining waters surrounding the Hawaiian Islands are between 1,000 and 2,000 fathoms and over two-thirds are more than 2,000 fathoms deep.

TUNA AND BAIT RESOURCES: The two major types of commercial tuna fisheries of the Hawaiian Islands are:

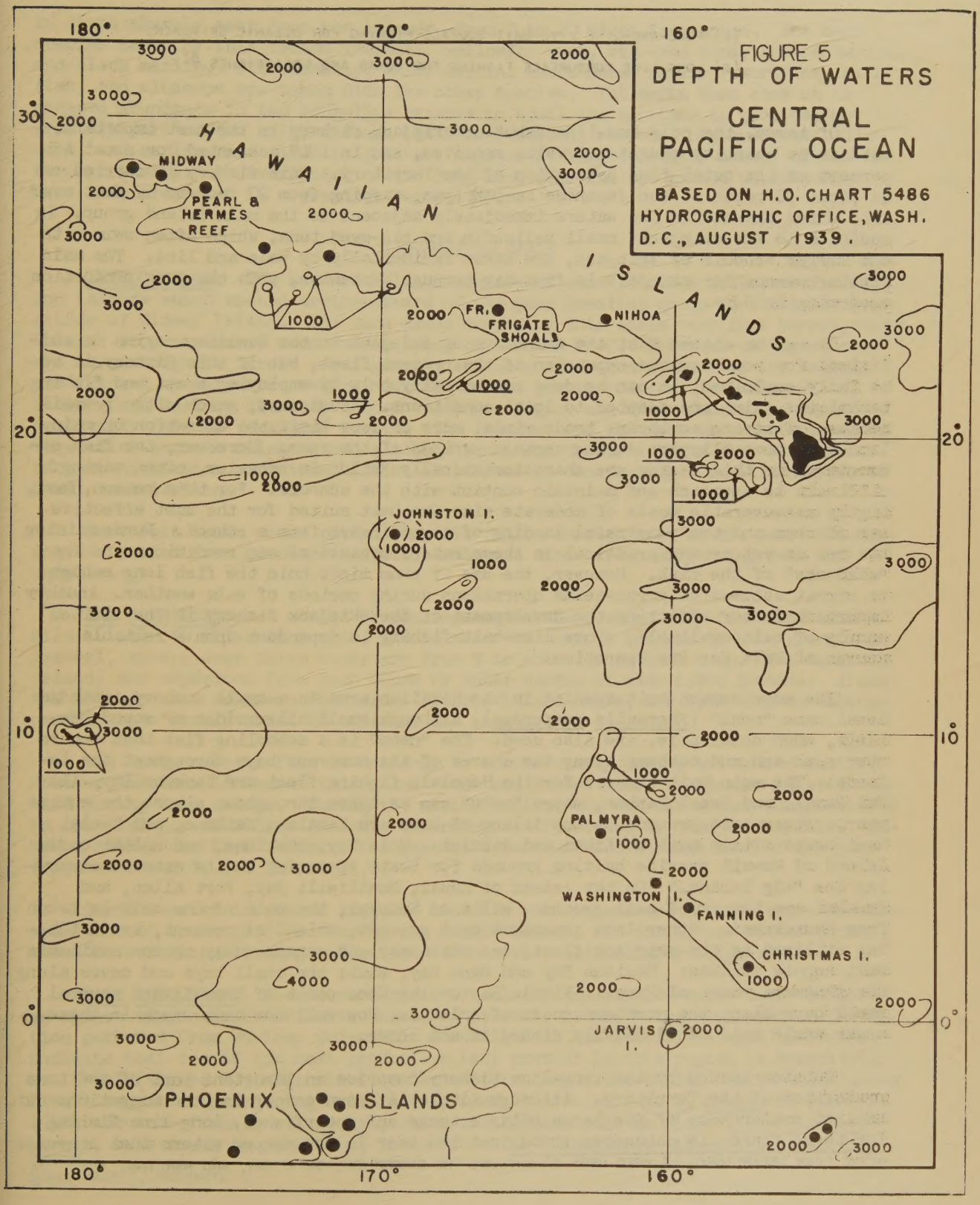


FIGURE 5
DEPTH OF WATERS
CENTRAL
PACIFIC OCEAN
BASED ON H.O. CHART 5486
HYDROGRAPHIC OFFICE, WASH.
D.C., AUGUST 1939.
180°
170°
160°
30°
20°
10°
0°
HAWAIIAN ISLANDS
MIDWAY
PEARL & HERMES REEF
FR. FRIGATE SHOALS
NIHOA
JOHNSTON I.
PALMYRA
WASHINGTON I.
FANNING I.
CHRISTMAS I.
JARVIS I.
PHOENIX ISLANDS

(A) POLE-AND-LINE LIVE-BAIT SURFACE FISHING FOR OCEANIC SKIPJACK.

(B) LONG-LINE SUBSURFACE FISHING FOR TUNAS AND SPEARFISHES.4/

Of these, the pole-and-line "aku" or skipjack fishery is the most important, both as to quantity caught and value received, and in 1947 accounted for about 45 percent of the total fish production of the Territory. This fishery is carried on by about 30 boats of the Japanese sampan type, varying from 27 feet to 92 feet overall, which operate in the waters immediately adjacent to the main island group. In addition to the skipjack, small yellowfin and big-eyed tuna, which often swim with the larger schools of skipjack, are taken incidentally by pole and line. The main fishing season for skipjack is from May through September, with the peak production occurring in July.

It can be stated that the abundance of skipjack in the Hawaiian region is sufficient for considerable expansion of the present fleet, but if this fishery is to be fully exploited, it can be done economically only by employing boats and fishing techniques which are adapted to local conditions. Rough seas, which often prevail because of strong northeast trade winds, more or less limit the operation of mainland-type tuna clippers during certain periods of the year. Moreover, the fish encountered in this region are characteristically "wild" in behavior, often making it difficult to approach and maintain contact with the schools. For this reason, fast, highly maneuverable boats of moderate size are best suited for the most effective use of chum and the successful landing of a good catch from a school. Purse seining has not as yet proved practical in these waters because of sea conditions and the "wildness" of the fish. However, the use of chum might hold the fish long enough to permit successful purse-seine operations during periods of calm weather. Another important factor affecting the development of the skipjack fishery is the limited supply of bait available, since live-bait fishing is dependent upon a reliable source of bait for its operation.

The most common bait species in the Hawaiian area is a small anchovy, with the local name "nehu" (Engraulis purpureus), although small silversides or round herrings, when obtainable, are also used. The "nehu" is a schooling fish that occurs over sand and mud bottoms along the shores of the numerous bays throughout the islands. The main bait centers for the Honolulu fishing fleet are Kaneohe Bay, Ala Wai Canal, and Pearl Harbor, where "nehu" can be taken throughout almost the entire year. Other bait grounds on the island of Oahu are Kahaluu, Waikane, and Heeia. Maui boats obtain bait at Kihei and Kahului. Hilo Bay, Kawaihae, and Kalihi on the Island of Hawaii provide baiting grounds for boats operating in the waters surrounding the "big island." On the island of Kauai, Nawiliwili Bay, Port Allen, and Hanalei are the chief bait grounds, while on Molokai, the bulk of the bait is taken from Kaunakakai. Other less important bait grounds, which, at present, are not being utilized by the skipjack fleet, and which may add considerably to the available bait supply include: Maalaea Bay and Hana Bay, Maui; the small bays and coves along the windward coast of Hawaii; Kiholo Bay on the Kona coast of Hawaii; and several small bays along the northern coast of Molokai. How well the bait stock in these areas would hold up if heavily fished is not known.

Catches landed by the long-line fishery comprise an important part of the tuna production of the Territory. Although little is known concerning the migrations and habitat preferences of the large pelagic tunas and spearfishes, long-line fishing for these fishes is conducted throughout the year in the deeper waters that increase

4/THE TERM SPEARFISHES IS USED HERE TO INCLUDE THE SWORDFISH, SAILFISH, AND MARLINS.

in depth sharply away from the islands—from 2 to 20 miles from shore. The main species taken by this method include: yellowfin tuna, big-eyed tuna, striped marlin, and black marlin. Occasionally, white marlin, short-nosed marlin, swordfish, sailfish, and albacore are taken with the other species. Yellowfin tuna show an increased abundance in the long-line catches in April and continue to provide the greatest part of the catch through the summer season, whereas, big-eyed tuna, albacore, and marlins are taken in greatest numbers during the winter months (November through April). A description of the long-line gear and the method of operation have been presented in a previous report.5/

LEEWARD ISLANDS

INTRODUCTION: The Leeward Islands consist of some 17 named banks, reef areas, and islands which extend northwestward of the main Hawaiian group to about the longitude of Midway Island. The land areas composing this chain vary from barren, rocky islands to a series of sand islets lying on a coral reef. The surrounding waters are warm enough to permit coral growth, and as a consequence, most of the islands are fringed by extensive reefs. Certain of the group, however, including Nihoa, Necker, and Gardner Pinnacle are of volcanic origin, and their shores are almost completely free of coralline growth. The islands, for the most part, are barren of vegetation and are uninhabited, although Nihoa and Necker islands show evidence of ancient habitation and Midway Island at present is occupied by a small United States Naval installation.

Northeast trade winds prevail in this region through most of the year; but during the period from October to April, southwest winds frequently bring rain and squalls.

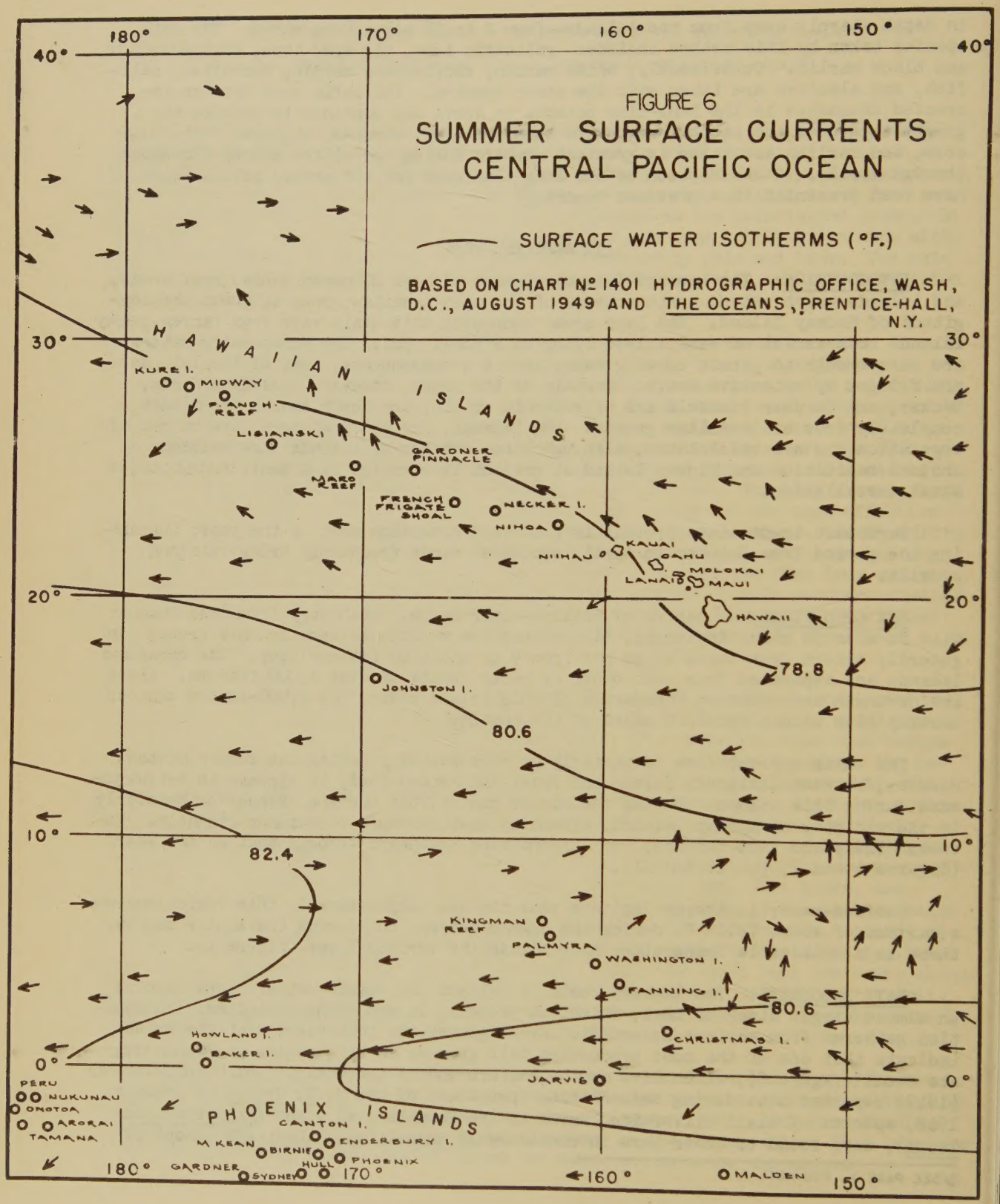
SEA CONDITIONS: A series of shallow-water banks, which vary from less than a mile to over 50 miles in length, lie between the various islands in this group. In general, waters over these banks are from 9 to about 40 fathoms deep. The banks and islands are separated from each other by water depths of over 1,000 fathoms. Along the northern and southern boundaries of this island chain, the 2,000-fathom contour usually lies within about 20 miles of the shoals.

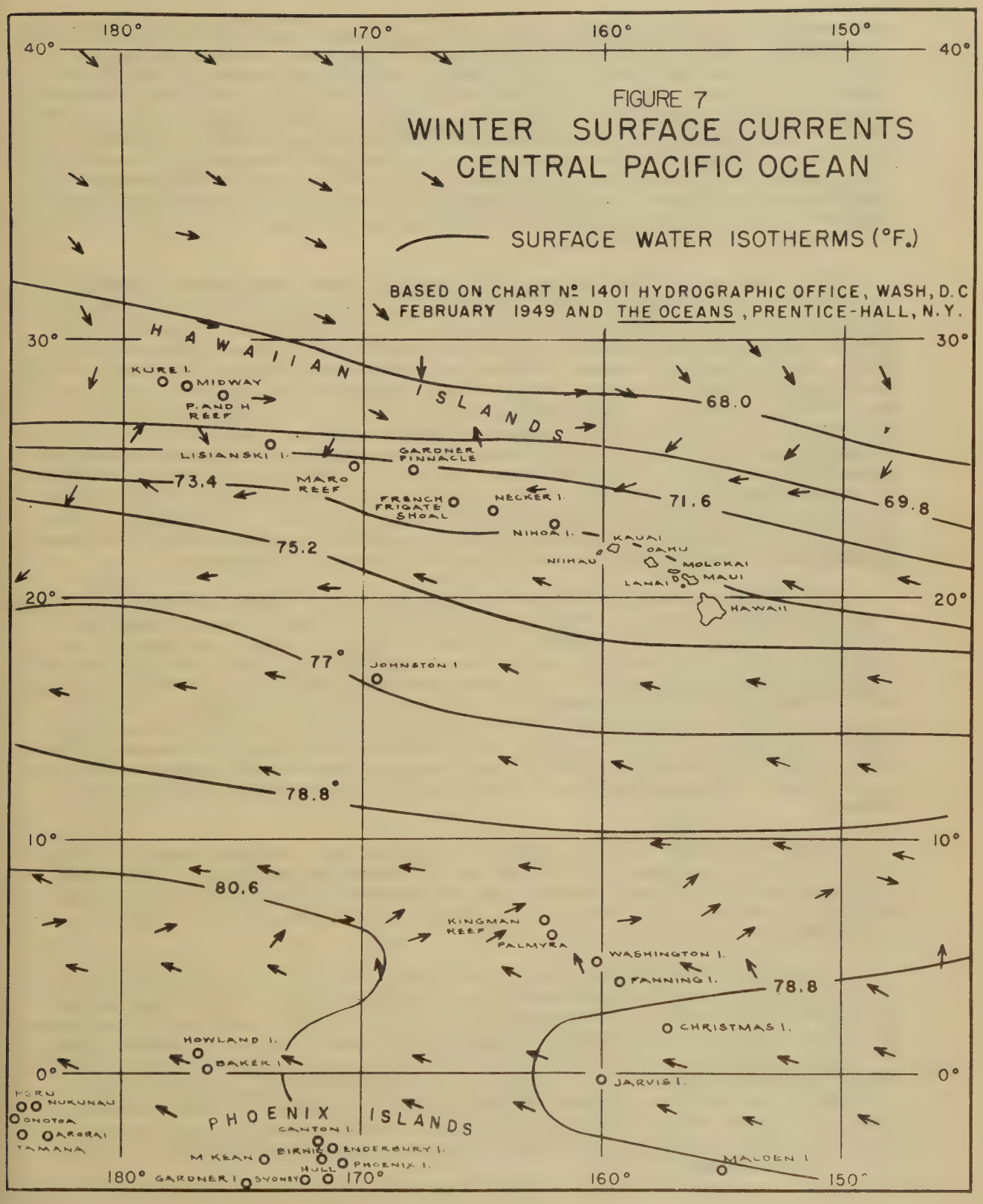
The main current flow is westerly or northwesterly during the summer months. However, between Lisianski Island and Pearl and Hermes Reef, it appears to set northward during this season. During the winter months, the current trends southeasterly in the vicinity of Midway Islands, extending southeastward to Gardner Pinnacle. Between Midway and Kure islands, the current sets southward through most of the year (figures 6 and 7, pp. 10 and 11).

Surface-water isotherms indicate that the sea temperature in this region reaches a maximum of about 78.8° F. during the summer season, but during the winter months, there is a noticeable temperature drop within the surface layer (figure 1).

BAIT RESOURCES: The leeward chain of islands and shallow-water banks support an almost virgin stock of bait, which, at present, is not being exploited. Information gathered from various scientific investigators and interviews with fishermen indicate that one of the most productive bait grounds in this region is French Frigate Shoal (figure 8), which lies on the eastern end of the chain. Smith and Schaefer (1949) reported that during bait-fishing operations of the M. V. Oregon in January 1948, species of small silverside, known to the Hawaiians as "iao" (Atherina insularum), were found to occur here in considerable quantities. About 450 scoops of

5/SEE PAGE 1, FOOTNOTE 1.


180°
170°
160°
150°
40°
30°
20°
10°
0°
FIGURE 6
SUMMER SURFACE CURRENTS
CENTRAL PACIFIC OCEAN
SURFACE WATER ISOTHERMS (°F.)
BASED ON CHART Nº 1401 HYDROGRAPHIC OFFICE, WASH, D.C., AUGUST 1949 AND THE OCEANS, PRENTICE-HALL, N.Y.
HAWAIIAN ISLANDS
KURE I.
MIDWAY
P. AND H. REEF
LISIANSKI
GARDNER PINNACLE
MARO REEF
FRENCH FRIGATE SHOAL
NECKER I.
NIHOA
NIIHAU
KAUAI
OAHU
MOLOKAI
LANAI
MAUI
HAWAII
78.8
JOHNSTON I.
80.6
82.4
KINGMAN REEF
PALMYRA
WASHINGTON I.
FANNING I.
80.6
HOWLAND I.
BAKER I.
CHRISTMAS I.
JARVIS
PERU
NUKUNAU
ONOTOA
AROROAI
TAMANA
PHOENIX ISLANDS
CANTON I.
M. KEAN
BIRNIE
ENDERBURY I.
GARDNER
SYDNEY
HULL
PHOENIX
MALDEN


180°
170°
160°
150°
40°
30°
20°
10°
0°
FIGURE 7
WINTER SURFACE CURRENTS
CENTRAL PACIFIC OCEAN
SURFACE WATER ISOTHERMS (°F.)
BASED ON CHART Nº 1401 HYDROGRAPHIC OFFICE, WASH, D.C
FEBRUARY 1949 AND THE OCEANS, PRENTICE-HALL, N.Y.
HAWAIIAN ISLANDS
KURE I.
MIDWAY
P. AND H REEF
LISIANSKI I.
GARDNER PINNACLE
MARO REEF
FRENCH FRIGATE SHOAL
NECKER I.
NIHOA I.
KAUAI
OAHU
NIIHAU
MOLOKAI
MAUI
LANAI
HAWAII
68.0
73.4
71.6
69.8
75.2
77°
78.8°
JOHNSTON I
80.6
KINGMAN REEF
PALMYRA
WASHINGTON I.
FANNING I.
78.8
CHRISTMAS I.
HOWLAND I.
BAKER I.
JARVIS I.
PERU
NUKUNAU
ONOTOA
AROAI
TAMANA
PHOENIX ISLANDS
CANTON I.
M KEAN
BIRNIE
ENDERBURY I.
HULL
PHOENIX I.
GARDNER I
SYDNEY
MALDEN I

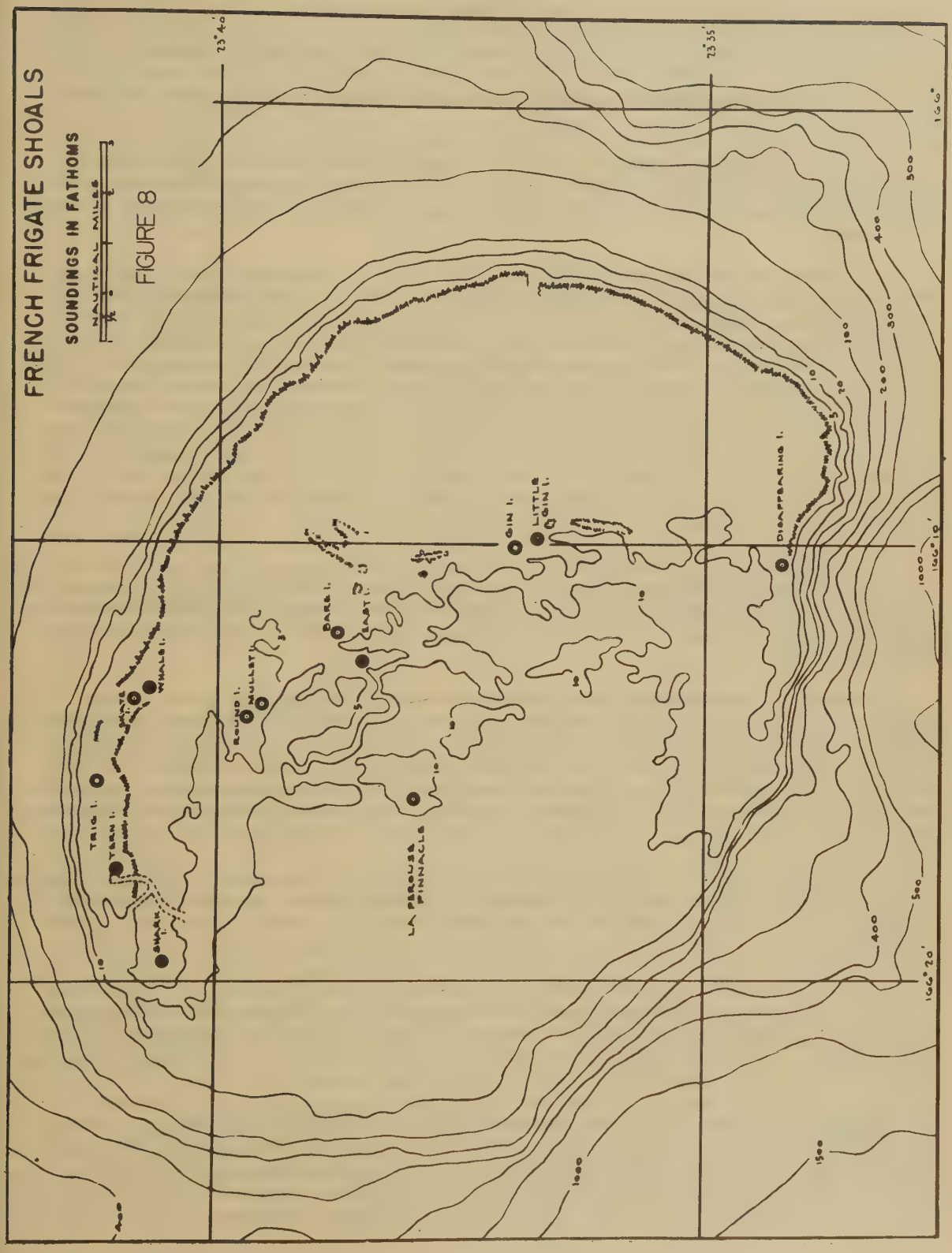
this species were taken by the Oregon on the sandy beaches surrounding East and Tern islands during 10 days fishing and exploring. The following August the Oregon returned to the area for a second load of bait. Eckels (1949) reported that about 300 scoops of "iao" were caught in the shallow waters surrounding East Island during two days. An additional 78 scoops of the same species were taken during two days fishing off Gin and Little Gen islands, and over 500 scoops were caught in depths of 3 to 15 feet off Tern Island during two days. He concludes, "whether the stock of 'iao' present in this area would maintain a sizable bait fishery is not known. However, quantities of bait sufficient to supply at least two or possibly three tuna clippers the size of the Oregon were present during the August period when the vessel was at French Frigate Shoals."

On a visit to the Shoal by the author aboard a Coast Guard vessel on May 18, 1949, the waters surrounding several of the small islets were scouted for bait. A three-day "Kona" storm had ended the day prior to our arrival and the small fish were not seen along the beaches, but occurred in the deeper waters among the coral heads. Most of the islets are surrounded by sand beaches, which are frequently interrupted by patches of coral. Bait-netting operations could be carried on along many of these beaches at places where breaks in the coral occur. A surround-type net, between 80 and 100 feet in length and about 12 feet in depth, of one-half inch stretched mesh, and with a heavily leaded bottom, would perhaps be most satisfactory. The net could either be stretched across the outer limits of a sand beach and worked in toward shore, or it could be paid out from a skiff, with one end of the net held on shore as the skiff moved in a half circle around the bait. The transfer of fish from the bunt of the net could be made, either to a skiff equipped with a bait compartment or to shallow-draft (not more than 18 inches) bait receivers.

Information gathered from fishermen stationed at Tern Island indicate that the "iao" periodically occur in large schools in the shallow waters surrounding most of the islets at French Frigate Shoal. They appear to be quite tame and are not easily frightened when surrounded by a net. A small round herring, known locally as "piha" (Spratelloides delicatulus), is found throughout the area, but it occurs sporadically, as is characteristic of this species in the Hawaiian Islands. Both "iao" and "piha" apparently occur in greatest abundance during the summer months. It has been observed that during the winter months, when stormy weather conditions frequently prevail in this area, these small fish often disappear from the sand beaches surrounding the islets. Consequently, bait fishing may at times be restricted during the season.

Several investigators have reported the occurrence of various species of small fish in certain areas lying to the northwest of French Frigate Shoal. This information is scanty and is not supported by any commercial attempts to exploit these bait stocks, but it does offer some data regarding the distribution of bait fish in the Leeward Island chain.

Pietschman (1938) reports "many individuals" of "iao," "piha," and "aholehole" (Kuhlia marginata) at Pearl and Hermes Reef. Galtsoff (1933), in a biological survey of the area from July 15 to September 1, 1930, stated that many small fish abound in the lagoon at Pearl and Hermes, among which he listed "iao" and a species of mullet (Mugil cephalus). It is not known whether these various species occur in this area in sufficient quantities to support a sizable bait fishery. However, it is to be expected that the large lagoon and reef areas should support a fairly abundant bait stock, since the topography of this area is very similar to French Frigate Shoal, which lies at the eastern end of this chain, and where considerable quantities of bait are present.


FRENCH FRIGATE SHOALS
SOUNDINGS IN FATHOMS
NAUTICAL MILES
0
1
2
3
FIGURE 8
23°40'
23°35'
166°
166°15'
166°20'
TRIG I.
TERN I.
SHARK I.
WHALE I.
ROUND I.
NULLET I.
BIRD I.
EAST I.
GIN I.
LITTLE GIN I.
DISAPPEARING I.
LA PEROUSE PINNACLE
10
20
100
200
300
400
500
1000
1500

At Lisianski Island, Pietschman reports the occurrence of "piha" but says nothing about its abundance. Fowler and Ball (1925) state that the sandy bays and coves of this island supported "myriads of a relatively small number of species," among which "aholehole" was recorded as occurring in the millions. "Piha" and "iao" are also reported. These authors also reported "aholehole" as being common at Laysan Island.

Recent information indicates that "aholehole" is abundant at Midway Islands during the spring and early summer months. "Iao" similarly occur in some numbers during the spring months. Nothing more is known concerning the occurrence of other bait species.

Our observations and those made by the scientific personnel aboard the Oregon and others in the Leeward Island chain indicate that this area appears to be the most promising source of bait for tuna vessels operating in this region. However, no definite conclusions can be stated at this time as to the magnitude of the bait supply and variations in abundance through the year. It will be necessary for frequent and extended observations to be carried on at various intervals through the year and over the entire area. If it could be shown that the stock of "iao" at French Frigate Shoal is sufficient to provide a supply of bait for intensive live-bait operations, an independent live-bait fishery, which would catch and hold bait in containers from which tuna boats could obtain bait, could easily be established and maintained on one of the islets, or clipper ships could obtain bait by the methods already described.

TUNA RESOURCES: There is some information available concerning the distribution of tunas in the adjacent waters of the Leeward Island chain, although at present this region is not being exploited for these pelagic fish. Various reports indicate that yellowfin tuna, oceanic skipjack, and "kawakawa" may occur in this region in important quantities.

During the exploratory fishing cruise of the N. B. Scofield (in the summer of 1948) in the waters extending northwestward of the Hawaiian Islands proper to French Frigate Shoal, oceanic skipjack were found to be plentiful over the shallow banks in this area. Yellowfin tuna were also present but, almost invariably, they were found mixed with skipjack. "Kawakawa" were taken exclusively in the shallowest waters over the banks. The best fishing in this region was on the slope of the banks, where the sea bottom dropped off rapidly from 40 or 50 fathoms to prevailing depths.

In August 1948, the Oregon explored the banks to the northwest of French Frigate Shoal for tuna. "Kawakawa" were found to be rather numerous between Brooks Bank and Gardner Pinnacle, but few yellowfin and oceanic skipjack were encountered. Nevertheless, some fish were caught by trolling and by pole and line.

During the summer of 1948 several fishermen stationed at French Frigate Shoal fished long lines for yellowfin tuna in the waters lying just outside the fringing reef along the northeast side of the Shoal. Using 16 baskets of gear, with a total of 80 hooks, they were able to catch from 25 to 40 fish a day, which shows a higher catch per unit of effort than is common in Hawaiian waters.

During our cruise to French Frigate Shoal in May 1949, seven schools of tuna were sighted in the vicintiy of the Shoal. One school was identified as yellowfin tuna and appeared to be about three quarters of a mile in length at the surface. Another school, tentatively identified as oceanic skipjack, was about the same size as the school of yellowfin. The other schools seen were not close enough to permit

identification. Six of these schools were seen under flocks of birds. In addition, about 15 flocks of birds, which appeared to be "working" over schools of fish, were sighted between Nihoa and French Frigate Shoal.

Discussions with Hawaiian fishermen (engaged in hand lining for bottom fish over the shallow-water banks in this region) indicate that schools of yellowfin, oceanic skipjack, and "kawakawa" are invariably seen on the cruises to and from the fishing grounds. Schools of yellowfin, a mile or so in length at the surface, have been seen. They report oceanic skipjack and yellowfin as most common during the summer months, although some tuna are caught on trolled lures throughout the year.

THE LINE ISLANDS

INTRODUCTION: The Line Island chain is composed of some 17 scattered atolls and reef areas which run from about 6° N. latitude to just below the Equator near 160° W. longitude. One of the largest coral islands in this group is Christmas, which has a total land area of about 160 square miles. These islands are separated from each other by waters which are over 1,000 fathoms deep. Most of the islands are surrounded by fringing reefs enclosing a central lagoon. Outside of the reefs the sea bottom drops off to great depths within only a short distance of the limits of the coral.

The prevailing winds in this region blow from the east through the year. Frequent line squalls, usually only of short duration, blow from the southeast; however, fair weather may be expected during most of the year.

SEA CONDITIONS: The Line Islands are situated partially within the region of the equatorial countercurrent, and as a consequence, the conditions produced by the water movements in this zone may be expected to greatly affect the biological productivity of the surrounding seas.

The north equatorial current originates off Central America and remains in the Northern Hemisphere as it moves across the entire Pacific Ocean. In the region of the Line Islands, it extends southward to about 8° N. latitude during the greatest part of the year. The south equatorial current is present on both sides of the Equator, reaching northward to about 5° N. latitude. Lying between the two, the equatorial countercurrent flows eastward, reaching velocities up to two knots at the surface, as it moves farther northward from the Equator during the northern summer. As a result of forces arising from the earth's rotation, causing transverse circulations, divergences arise at the northern boundary of the equatorial countercurrent and along the Equator, while at the southern boundary of the countercurrent, a convergence occurs. These current divergences (at the Equator and at the northern boundary of the countercurrent) cause the deeper waters, which are rich in plant nutrients, to rise to the surface. Within the surface layer, where light is sufficient for photosynthetic processes, these nutrients may be utilized by the microscopic plant life living in this zone. These plants provide the basic food source, which indirectly provides the food supply for the large pelagic fish. It is to be expected, therefore, that the tunas may be encountered in abundance in these latitudes, as indeed is the case farther to the westward, where (prior to World War II) the major tuna fishing areas exploited by the Japanese in the South Seas centered between 0° and 7° N. latitude, extending as far eastward as 160° E. longitude. The data compiled by Japanese research vessels operating in this region point out that the best fishing grounds, for the most part, were located within the limits of the equatorial countercurrent, with yellowfin tuna heading the list of species caught.

Surface water isotherms show little horizontal variation in sea temperatures in the region of the Line Islands; the only apparent difference occurs at the two extremes of the year (figures 6 and 7). The depth to the thermocline, however, varies greatly in this zone due to the upwelling associated with the equatorial countercurrent. The data recorded by the Oregon in February 1948 (figure 9) indicates that, near the Equator, the least depth to the thermocline was found to be about 270 feet, while the greatest depth was 400 feet at 1° N. latitude. The Carnegie's findings, similarly, indicate a great variation in depth to the thermocline in a north-south direction in the waters lying east of this island chain (figure 10). The thermocline lies closest to the surface, of course, where the upwelling occurs along the divergences.

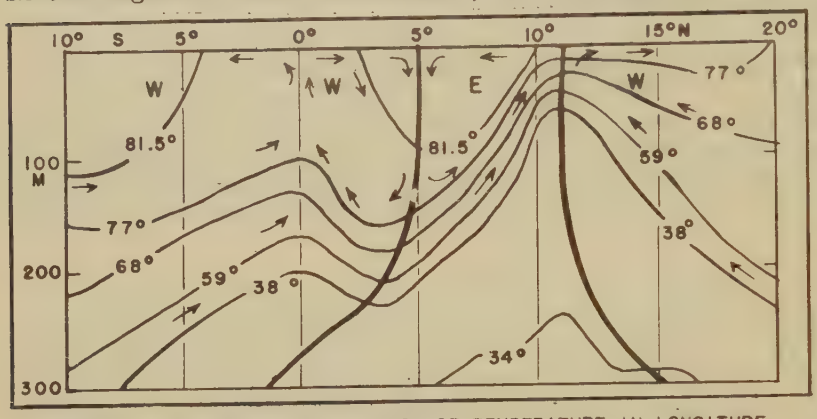
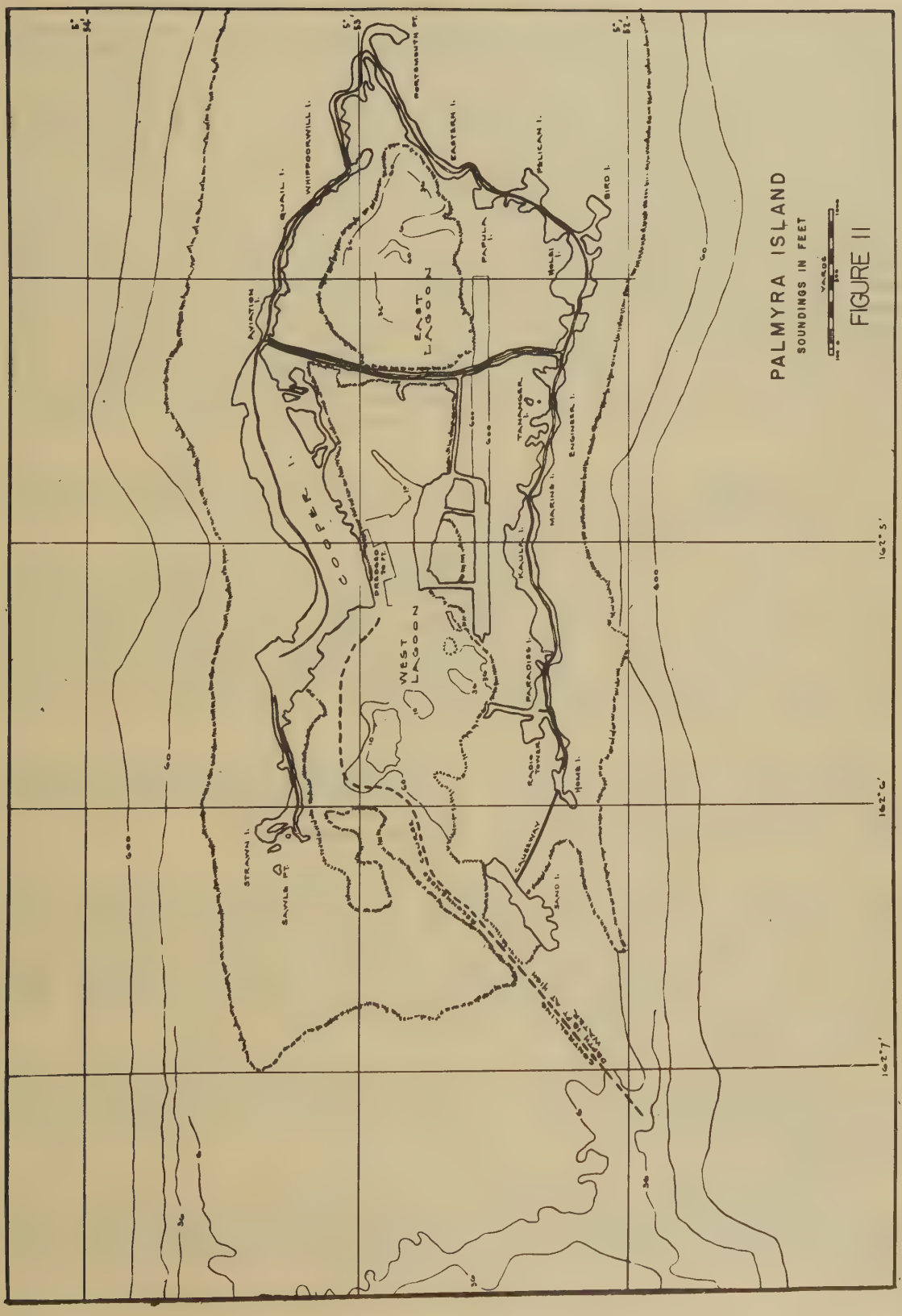


FIGURE 10 - VERTICAL DISTRIBUTION OF TEMPERATURE IN LONGITUDE 140° W., BETWEEN 10° S. AND 20° N. IN THE PACIFIC OCEAN. ACCORDING TO OBSERVATIONS MADE BY THE CARNEGIE, OCTOBER 1928 (REPRODUCED FROM THE OCEANS, PRENTICE HALL, N. Y.).

The variations in thermocline depth must be taken into consideration with respect to long-line operations in this area, for in all likelihood, the vertical distribution of the tunas is influenced to a large extent by subsurface temperature conditions. The results of the Japanese exploratory investigations, for example, indicate that water temperature at the 100-meter stratum is most closely related to long-line fishing for yellowfin tuna in the equatorial regions lying to the westward of the Line Islands. Within the limits of the equatorial countercurrent (where yellowfin were found to be most abundant), the best catches were made when temperatures at a depth of 100 meters were over 20° C. (68° F.)

BAIT RESOURCES: The only definite information on the bait fish resources of this area is that pertaining to Palmyra Island (figure 11). On a survey trip to Palmyra by the author in June 1949, the entire island was scouted for bait. It was immediately obvious that fish of the size suitable for use as live bait were most plentiful in East Lagoon. These were primarily species of the mullet family (Mugil crenilabis, M. vaigiensis, and M. trichilus), varying from one inch to over 6 inches in length. The mullet occurs here in schools of varying size, from a few scoops to a hundred or more scoops, and could be seen swimming at the surface over the entire lagoon. Small milkfish (Chanos chanos), about 2 or 3 inches long, were also in evidence along the beaches. In West Lagoon, small goatfish, from one to 4 inches long, occurred in quantity along the north shore of the lagoon. According to several of the natives, the goatfish are fairly abundant along the sand beaches during June, July, and August; however, it is doubtful that they exist in quantities sufficient to supply anything but very limited fishing operations.

In February 1949, the commercial tuna clipper Calistar prospected Palmyra Island for bait. Using a Galapagos net in the shallow waters of East Lagoon, only about 8 scoops of 5-inch mullet were taken. From discussions with Civil Aeronautics Administration (CAA) personnel stationed on the island it was learned that the small mullet, which, apparently, are most abundant during the summer months, were not in evidence during the Calistar's explorations in the early part of the year.


PALMYRA ISLAND
SOUNDINGS IN FEET
FIGURE II
EAST LAGOON
WEST LAGOON
PAPUA
PELICAN I.
BIRD I.
AVIATION I.
WHIPPOORWILL I.
EASTERN I.
TANNOGAI
KAULA I.
MARINE I.
ENGINEER I.
PARADISE I.
HOUSE I.
SAND I.
STRAWN I.
162° 5'
162° 6'
162° 7'

It is not known whether the stock of mullet at Palmyra is sufficient to support a reliable bait fishery, since the occurrence of the small-size fish is apparently a seasonal phenomenon. Furthermore, how suitably this bait would survive long-distance transportation and handling has not been determined. Nevertheless, if the stock of mullet, found to be present during our visit to the area, would hold up through the summer months for commercial exploitation, East Lagoon would probably prove the most suitable bait grounds. A surround-type beach seine, about 200 feet long, and at least 5 feet deep, of 1/2-inch stretched mesh, with a cork float line, large bunt, and a heavily leaded bottom would be most satisfactory for use along the sandy beaches; however, captured bait would have to be transported a distance of about 4 miles to the dock area. This could be accomplished only with greatest difficulty. It would be necessary to use either a shallow-draft (not over 2 feet) bait receiver, or a skiff with a built-in bait compartment. The receiver could be towed out of the lagoon through the southeast channel and worked along the coral platform on the southern side of the atoll. Numerous coral patches, some of which are completely uncovered, would be encountered, making navigation difficult. It must also be pointed out that the coral shelf extends only about 250 yards from the shore line on the south, with heavy rollers frequently breaking over the edge of the reef and reaching to the shore. A similar condition exists along the northern side of the atoll.

TUNA RESOURCES: Various observations on the tuna stock of the Line Islands region indicate that oceanic skipjack and yellowfin tuna appear to exist in the area in commercially important quantities.

On the exploratory cruise of the Oregon through the Line Islands in February 1948, numerous schools of oceanic skipjack were seen on the run between Palmyra and Jarvis, and between Jarvis and Christmas Island. A number of skipjack and small yellowfin were taken by trolling, and several schools of yellowfin were fished at Jarvis and Fanning, producing some fish; however, around Christmas Island only one large school of fish was seen. Many of the schools encountered in this region were moving too fast to permit fishing.

During the summer of 1948, the N. B. Scofield explored the areas surrounding Johnston Island and found an abundance of fish, mostly skipjack, in the immediate vicinity of the island. Occasionally, mixed schools of skipjack and yellowfin were seen, but no schools of straight yellowfin were encountered.

On the fishing and exploratory cruise of the Calistar in the Line Islands region in February 1949, live bait fishing was found to be best at Fanning Island, where about 50 tons of yellowfin were taken close to the beach. At Palmyra, another 15 tons of yellowfin were taken in the waters lying to the west of the Island. It may be of interest to note that the tuna were located by means of trolled lines. As the fish rose to the surface, chumming was begun. A number of tuna schools (possibly skipjack) was seen in the open ocean, but the fish were at all times moving too fast to permit fishing.

Interviews with CAA personnel stationed at Palmyra confirmed the fact that tuna are in evidence in the vicinity of the island the year round, and are frequently taken on troll lines within a short distance of the barrier reef along the west side of the Island.

It can be expected that oceanic skipjack and yellowfin tuna occur in the waters of the Line Islands in sufficient quantities for commercial exploitation, but further research is needed to determine at what seasons, areas, and depths tuna occur in

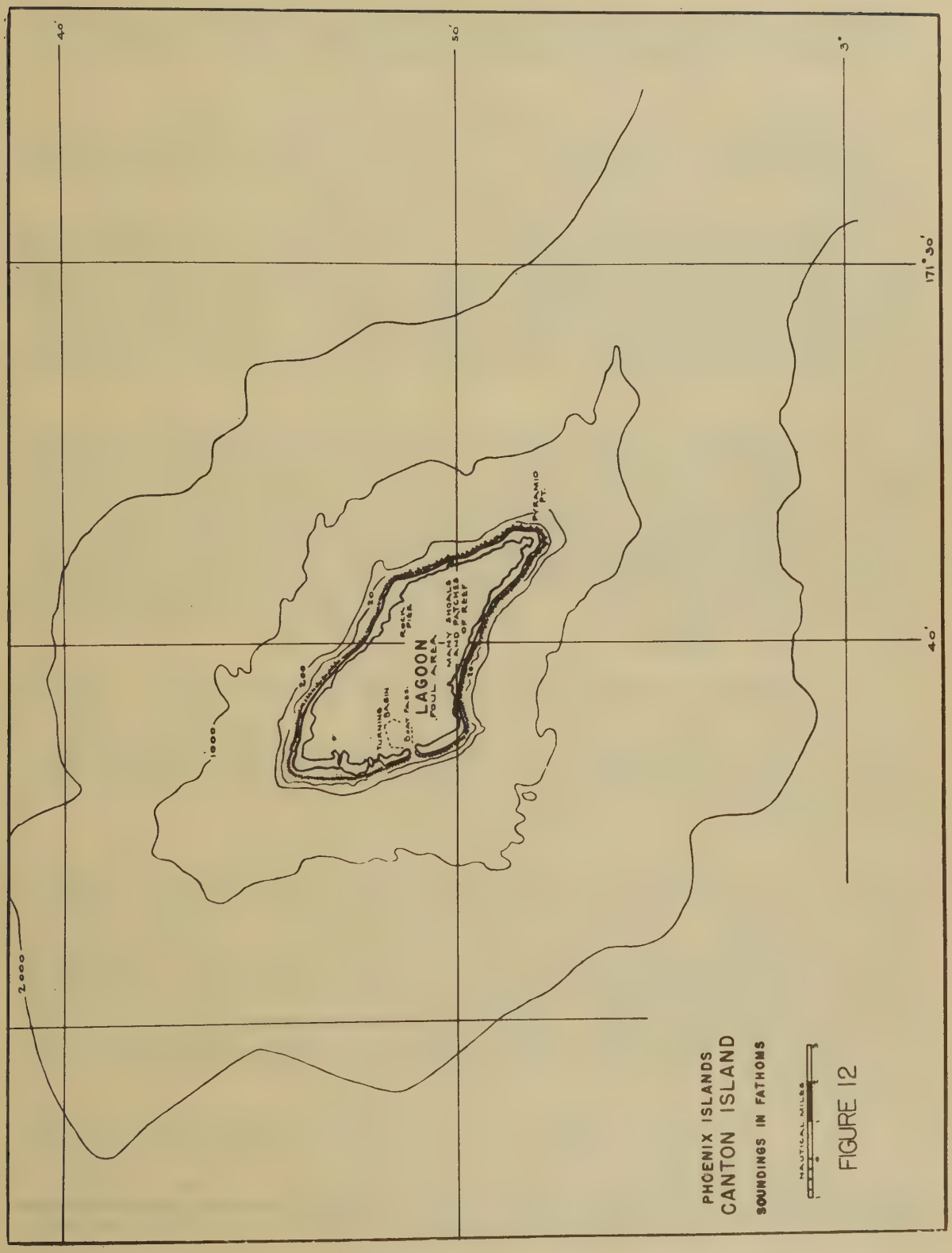

4°
50'
3'
171°30'
40'
LAGOON
POOL AREA
MANY SHOALS AND PATCHES OF REEF
AV. RANID PT.
TURNING BASIN
2000
1000
PHOENIX ISLANDS
CANTON ISLAND
SOUNDINGS IN FATHOMS
NAUTICAL MILES

FIGURE 12

quantity, and to discover those relationships between the peculiarities of the environment and the distribution and behavior of the tunas which will make possible the prediction of successful fishing areas, depths, and methods.

CANTON ISLAND

INTRODUCTION: Canton Island lies outside the Hawaiian archipelago, but the results of a survey of this atoll are included in this report to provide general information on the tuna and bait resources of this region.

During our[6/] visit to the Island on June 28 and 29, 1949, the joint facilities of the British and American administrative agencies were made available for conducting a survey of the area. By means of a small motor launch, we were able to explore parts of the lagoon and certain waters lying outside the fringing reef along the west side of the Island. Collections of various species of small fish, that might be suitable for use as live bait, were made by means of a dip net and a light at night. Additional specimens were also collected inside the lagoon by native fishermen using a beach seine.

Canton Island, the largest and most northerly of the Phoenix group, is a triangular coral atoll located about 1,660 miles southwest of Honolulu at 2°50' S. latitude and 171°43' W. longitude (figure 12). The east or windward side is approximately 9 miles long in a southeasterly-northwesterly direction and the shortest lee side is about 4 miles in a north-south direction. The atoll consists of a narrow strip of land, from 100 to 500 yards in width, that forms a rim enclosing a large lagoon. The main channel leading into the lagoon is about 100 yards wide and has a controlling depth of 28 feet, with over a 6-knot current at the strength of tidal flows. There is also a small boat channel located about one mile north of the southwest point of the island.

The fringing reef extends only about 200 yards from the shore line, except at the three corners, where it extends outward about 400 yards. The waters outside the reef drop off to depths of over 300 fathoms within a few hundred yards. The waters in the lagoon reach a maximum depth of 12 fathoms, but the bottom is interrupted by numerous reefs and coral heads. At low tide, the sandy beaches within the lagoon extend inward about 100 yards along the northwest and east sides before coral heads are encountered.

A coral slab pier, about 100 yards long, extends into the lagoon from the northeast rim, near its midpoint. A turning basin, about 550 yards long, 525 yards wide, and 25 feet deep, lies adjacent to the pier, providing excellent docking facilities for large vessels. Two 20' x 40' reefer buildings, which were formerly used by the Armed Forces during the war, are located near the docksite. The refrigeration machinery is nearly intact, but would have to be reconditioned before it could be put into operation. Various wooden frame buildings that could be used as maintenance shops and storage warehouses are available. A limited amount of Diesel fuel is available at the docksite for vessels operating in the area. The supply of fresh water is very limited; however, unlimited amounts of slightly brackish water are available.

There is an artificial pond, which was built by the Armed Forces during the war, located on the southwest shore of the lagoon at a point about 1-1/2 miles from the docksite. The pond is about 75 yards in diameter and has a small raceway built up from the bottom of the entrance, so that at low tide, water is retained within

6/STANLEY PETERSON, FISHERY ENGINEER, POFI, ACCOMPANIED THE AUTHOR, AND OBSERVATIONS WERE MADE JOINTLY.

the enclosure. This relatively shallow body of water might serve as a holding pond for live bait. Bait from the pond could easily be carried to the pier by means of a shallow draft (1 to 1-1/2 feet) bait receiver and power skiff.

The prevailing winds in this region blow from the east with an average velocity of 12 to 18 knots. Little rain falls on the Island itself, but off the Island frequent rain squalls occur.

SEA CONDITIONS: The sea bottom surrounding Canton Island drops off rapidly to great depths, just outside the fringing reef. The 1,000-fathom curve lies within about two miles of the reef, while the 2,000-fathom contour extends outward no less than 7 miles from shore. A deep-water trough (over 3,000 fathoms) lies to the northwest of the island. Depths in excess of 1,000 fathoms separate Canton from Enderberry Island which lies to the southeast. Comparison of summer and winter surface water isotherms shows little seasonal variation in sea temperature, the surface water remaining close to 80.6° F. through the year (figures 6 and 7). The prevailing current in this area sets almost due west.

BAIT RESOURCES: Within the lagoon, several species of mullet (Mugil vaigiensis and M. crenilabis), from 1 inch to over 12 inches long, were evident in considerable quantities. They appear to be the most common fish here and provide the chief food fish for the natives. Numerous schools of small round herring (Spratelloides delicatulus) were in evidence along the beaches during the afternoons, but disappeared from these areas shortly after sundown. None of this species were present in the light collections at night. "Aholehole" (Kuhlia sandvicensis) were also present in the lagoon and a few were taken by seining. The natives reported that this species is most abundant here during the spring months. Various species of small goatfish were also seen in varying abundance in the lagoon, but were not evident in sufficient quantities to permit any statement as to their availability for use as bait. There were apparently no members of either the silverside or anchovy families here; at least, these fish were not seen and they were not present in the collections.

The observations made at Canton during this survey indicate that the bait stock within the lagoon might prove to be adequate for a limited number of live-bait tuna vessels, but how well this stock would stand up under continued fishing is not known. The best baiting grounds for the various species listed above appeared to be located over the uninterrupted sand beaches along the northeast and northwest shores inside the lagoon. A surround-type net (see p. 18) could be used to best advantage, as many of the beaches here are devoid of coralline growth, and at high tide, the waters off the shoal areas are of sufficient depth to permit its operation.

TUNA RESOURCES: During our stay at the Island, several large schools of yellowfin tuna were seen within several hundred yards of the fringing reef along the west side of the Island, and in each case the fish were under flocks of "working birds." A local fishing party fished for skipjack on the afternoon of our last day's visit. Two fishermen landed 15 fish on a pole and jig in a period of about 20 minutes. They estimated the size of the school fished to be "about five acres." CAA personnel, stationed on the island, reported that schools of both yellowfin and oceanic skipjack are in evidence through the year, but appear in greater numbers during the winter months. So far as is known, the tuna resources of this area have never been exploited commercially.

It may be expected that skipjack and yellowfin tuna exist in this region in commercial quantities, but the limited nature of this survey precludes any conclusions as to the relative abundance of these species in different areas and at different seasons.

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PRELIMINARY FISHERIES SURVEY OF THE HAWAIIAN-LINE ISLANDS AREA[1/]

PART III - THE LIVE-BAIT SKIPJACK FISHERY OF THE HAWAIIAN ISLANDS

By Fred C. June*

INTRODUCTION

The Hawaiian name for the skipjack tuna, Katsuwonus pelamis, is "aku." Presumably, it is the same species that is found throughout the tropical waters of the Pacific Ocean and other warm seas of the world (Kishinouye, 1923; Godsil and Byers, 1944). In the waters about the Hawaiian Islands, where it occurs in great numbers, the skipjack is the object of a rather intensive localized fishery. In terms of poundage and value to the fishermen, it is the most important commercial fish in the Territory. In 1948, total skipjack landings for this island group were in excess of 8,355,000 pounds, which was the largest catch since the fishing fleet resumed operations following a break during World War II. The largest annual catch recorded was for 1940, when over 13,420,000 pounds of skipjack, valued at $527,666, were taken from these waters. The previous record catch was in 1937, when landings amounted to over 12,787,000 pounds, valued at $497,037. The annual skipjack production for the period 1937-1948 is shown in figure 1.

During the war years the fishing fleet became virtually inactive, and complete catch records are not available for this period. The fish catch was not reported by species for the first two months of 1944, but skipjack landings for the last ten months of that year amounted to roughly 732,000 pounds. By the end of 1945, the skipjack fleet had regained its prewar size; however, fishing that year proved to be poor, and the total production amounted to only 3,907,000 pounds.

As in the United States, the skipjack is utilized primarily for canning. The bulk of the catch in the Islands is processed by a single cannery which packs the fish for the local market and for shipment to the U. S. mainland. Important quantities are also sold on the fresh market, for the skipjack is an important item in the diet of many of the Oriental peoples, who prefer it in the raw form or as dried fish.

TABLE OF CONTENTS

	PAGE
DESCRIPTION AND NOTES ON BIOLOGY OF SKIPJACK	2
DEVELOPMENT OF THE FISHERY	3
FISHING BOATS AND CREWS	5
FISHING GEAR	6
BAIT:	7
BAIT SPECIES	7
BAIT FISHING GROUNDS	8
BAIT (CONT.):	
METHODS OF CAPTURE	8
FISHING METHODS	12
FISHING AREAS AND SEASONS	13
DISPOSITION OF THE CATCH	15
FUTURE POSSIBILITIES FOR THE DEVELOPMENT OF THE FISHERY	15
LITERATURE CITED	17

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1/ PART I - "THE HAWAIIAN LONG-LINE FISHERY," BY THE SAME AUTHOR APPEARED IN COMMERCIAL FISHERIES REVIEW, JANUARY 1950, PP. 1-23 (ALSO AVAILABLE AS SEPARATE NO. 244); PART II - "NOTES ON THE TUNA AND BAIT RESOURCES OF THE HAWAIIAN, LEEWARD, AND LINE ISLANDS," APPEARED JANUARY 1951, PP. 1-22 (ALSO AVAILABLE AS SEPARATE NO. 270).

DESCRIPTION AND NOTES ON BIOLOGY OF SKIPJACK

The skipjack, Katsuwonus pelamis (Linnaeus 1758), is a member of the tuna family (Thunnidae), although many taxonomists consider this species sufficiently distinct from other members of the tuna group to warrant placing it, together with the genera Euthynnus and Auxis, in a separate family (Katsuwonidae). The skipjack is a circumtropical species, ranging into temperate waters only during the warmer months. In the Pacific it is distributed from the coast of Canada off Vancouver Island southward along the coastlines of the United States and Central America to Chile, westward through the Hawaiian, Caroline, Marshall, and Marianas islands to St. Helens in Tasmania, thence northward through the southern parts of New South Wales, the Republic of the Philippines, Formosa, and along the entire Pacific Coast of Japan to northern Hokkaido (Kishinouye, 1923; Herre, 1940; Serventy, 1941; Clemens and Wilby, 1946; Roedel, 1948; Shapiro, 1948; Imamura, 1949). It is also found on both sides of the Atlantic, the Mediterranean Sea, and the Indian Ocean (Gunther, 1860; Day, 1878; Breder, 1929; LaMonte, 1945).

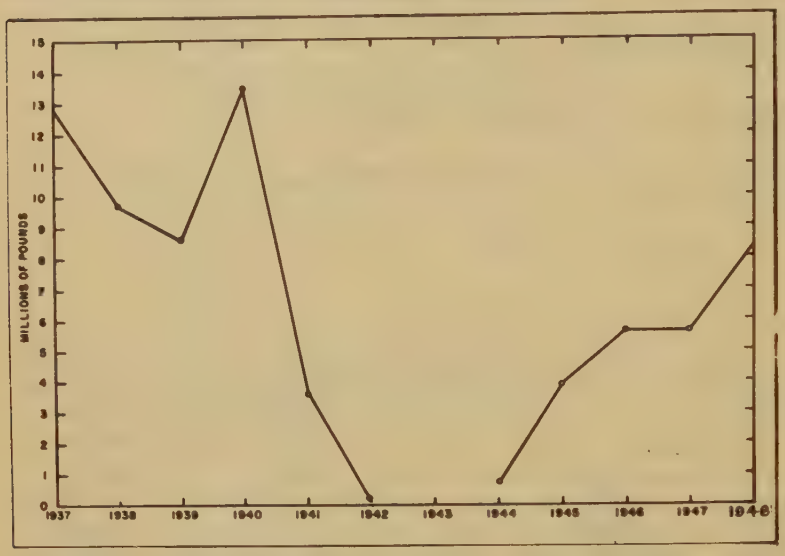

FIGURE 1 - SKIPJACK LANDINGS IN THE TERRITORY OF HAWAII, 1937-48. (NO DATA AVAILABLE FOR 1943. CATCH FOR 1944 INCLUDES MARCH THROUGH DECEMBER ONLY. DATA OBTAINED FROM THE CATCH RECORDS OF THE TERRITORIAL DIVISION OF FISH AND GAME).

The skipjack may be recognized by the four or more dark longitudinal stripes on the silvery belly and along the sides below the lateral line. The back is dark bluish-violet in life, becoming faded when the fish dies. The structure of the body is remarkably streamlined, with the first dorsal, pectoral, and ventral fins fitting into grooves when they are folded back. The body is nearly round in cross-section and pointed at both ends; it is naked except for a corselet of scales in the region around the pectoral fins and a few minute scales scattered over the remainder of the body. There is a median keel on each side of the slender caudal peduncle. A series of 7 to 9 finlets follow the second dorsal and anal fins. The head is rather large and conical. The mouth is terminal in position, with a single row of teeth on both jaws. The skipjack reaches a maximum weight of about 40 pounds. In Hawaiian waters the average size taken by the commercial fishery is approximately 15 pounds.

The skipjack is a fast-swimming, migratory fish that characteristically travels in schools which are often composed of many hundreds or even thousands of individuals. The schools found in Hawaiian waters are generally rather small, although Herre (op. cit.) mentions one school reported off the coast of Oahu that was about ninety miles long and ten miles broad. It has been demonstrated (Schaefer, 1948) that this species shows a marked tendency to aggregate by similar sizes. Schools are often encountered in which big-eyed and yellowfin tuna of comparable sizes travel together with skipjack.

Recent studies by Japanese investigators (Imamura, op. cit.; Suyehiro, 1938) on the feeding habits and stomach contents of this species have shown that its food consists of a great variety of organisms, the most important of which include squid, crustacea, sardines, anchovies, flying fish, etc. Kishinouye (op. cit., p. 454) stated that the food of the skipjack taken in Japanese waters generally consisted of "medium-sized plankton: amphipods, Squilla's larvae and other crustaceans, Pteropods, heteropods (chiefly Atlanta), calamaries, and immature or small fishes, etc."

Little is known concerning the spawning and early development of the skipjack inhabiting the Pacific Ocean. There is evidence, however, that one of the spawning areas for this species occurs in the eastern Pacific off the coast of Central America. Schaefer and Marr (op. cit.) report the capture of two juvenile specimens, 21 mm. and 44 mm. total length, in the oceanic waters off Costa Rica and upper Panama. Sexually mature and spent adults were also found to be present in the same area during the early months of the year. Marr (ibid.) indicates that a spawning ground for this species probably exists in or near the northern Marshall Islands area during the summer months. In addition, juvenile specimens, 113 to 183 mm. in length, have been collected in the vicinity of the Hawaiian Islands during the summer months (Eckles, 1949). There is some evidence that spawning also occurs in many other places in the Pacific (Kishinouye, 1927; Matsui, 1942; Hatai et al, 1941). Present knowledge indicates that the eggs, larvae, and juveniles, like the adults, are entirely pelagic.

DEVELOPMENT OF THE FISHERY

The skipjack fishery in the Hawaiian Islands has developed from a small-scale subsistence fishery carried on by the early native Hawaiians to the commercial fishery of today, conducted mostly by fishermen of Japanese ancestry. From the earliest times, Hawaiian fishermen sought the skipjack in the waters lying adjacent to the small villages scattered throughout the major islands in this group. The methods of capture and fishing gear used by these natives were similar to those employed in other parts of Polynesia (Beckley, 1883). The outrigger canoe was the characteristic craft found throughout this vast area. The canoes which were used for fishing in Hawaii varied from about 15 to 35 feet in length (Hornell, 1936). The smaller canoes usually carried but a single fisherman; however, when fishing specifically for skipjack, frequently several fishermen would combine forces. Two of the large canoes from which the outriggers had been removed were lashed parallel to each other with two cross-pieces. This simple arrangement provided a much safer sea-going craft than a single canoe carrying a lone fisherman, for the search for the skipjack often carried the fishermen considerable distances offshore. A double fishing canoe carried a crew of three in each hull, although only one man in each was actually occupied with the fishing; the others managed the canoe. The canoes were sometimes rigged with a single sail, but paddles were the most common means of propelling these craft.

The fishing technique used by the native Hawaiians for catching the pelagic skipjack were, in certain respects, similar to those practiced in the Islands today. Cobb's report, "The Commercial Fisheries of the Hawaiian Islands," published in 1903, gives an interesting account of native fishing:

> "ON REACHING THE FISHING GROUND THE FISHERMEN LOCATE THE FISH BY WATCHING THE SEA GULLS....AS SOON AS THE SCHOOL HAS BEEN SIGHTED THE CANOES ARE WORKED AROUND IN FRONT OF IT, AND THE FISH ARE ATTRACTED TOWARD THE BOAT BY MEANS OF A HANDFUL OR TWO OF SMALL LIVE BAIT THROWN INTO THE WATER.... TWO MEN STAND UP IN THE STERN OF THE BOAT, HOLDING IN THEIR HANDS A BAMBOO POLE ABOUT 12 FEET LONG WITH A LINE OF THE SAME

LENGTH ATTACHED, AND THE PEARL HOOK TIED TO THE END OF THIS LINE. BY A QUICK MOVEMENT THE LINE AND HOOK ARE SLAPPED VIOLENTLY ON THE SURFACE OF THE WATER AND THEN DRAWN TOWARD THE BOAT.... AS SOON AS THE FISH IS HOOKED, THE LINE IS SWUNG UP OVER THE FISHERMAN'S HEAD SO AS TO MAKE ALMOST A COMPLETE REVOLUTION. IT IS VERY NECESSARY THAT THE LINE SHOULD BE KEPT TAUT, AS, OWING TO THE FACT THAT THE HOOK HAS BUT A SLIGHT BARB, THE FISH WOULD SHAKE ITSELF LOOSE SHOULD THE LINE SLACKEN IN THE LEAST... AS THE HOOKED FISH IS DESCRIBING THIS REVOLUTION THE FISHERMAN SWINGS AROUND TO MEET IT AS IT NEARS HIM, BOWING OUT HIS RIGHT ARM. WHEN THE FISH COMES BETWEEN HIS ARM AND SIDE HE CLOSES THEM UP AND THE FISH IS CAUGHT, UNHOOKED, AND DROPPED INTO THE BOAT.

Containers of several different types were used for carrying live bait. The double fishing canoes usually carried a box about 20 feet long, 2 feet high, and 16 inches wide, lashed below the cross-pieces between the canoes. The sides and bottom of the box were perforated to allow sea water to enter and circulate.

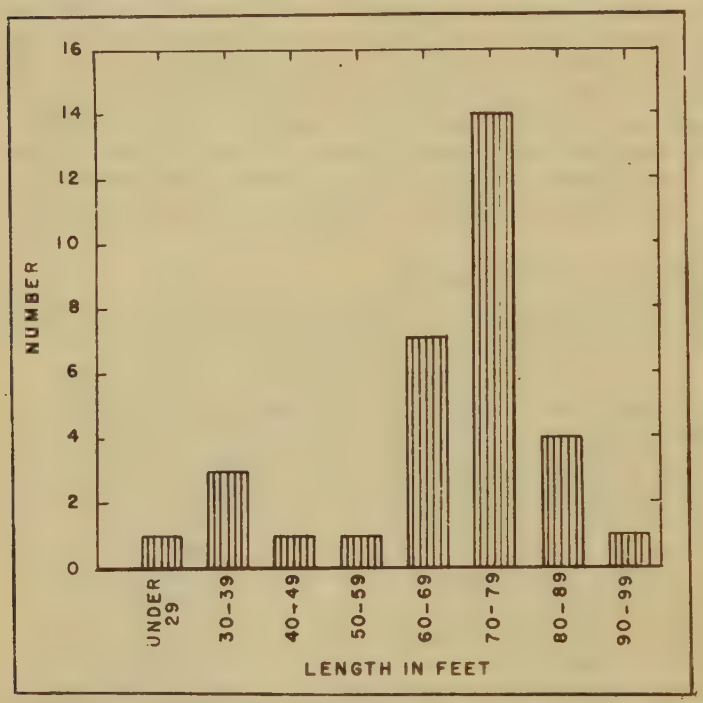

FIGURE 2 - LENGTHS OF THE 32 BOATS THAT FISHED EXCLUSIVELY FOR SKIPJACK IN THE TERRITORY OF HAWAII IN 1948.

At the time of Cobb's report, the skipjack fishery had already emerged as one of the more important commercial fishery enterprises in the Hawaiian Islands. In 1900, skipjack ranked fifth in poundage among the various commercial species caught in these waters, and total landings for that year amounted to slightly over 422,000 pounds. Of this catch approximately 401,000 pounds were sold on the fresh market, with the remaining 21,000 pounds processed as dried skipjack.

The early commercial development of the skipjack fishery in the Islands was due primarily to the efforts of the Japanese immigrants. According to a report, "Investigation on Fishing in Foreign Countries," published in 1938 by the Japanese government fisheries bureau, the first alien to be engaged in commercial operations in the Territory was a man named Kametaro Nishimura, an emigrant from Yamaguchi-ken, who began fishing here in 1885. It is not definitely stated, however, that Nishimura fished specifically for skipjack. In 1899, Gorokichi Nakasuji, a native of Wakayama-ken brought a fishing boat and gear from Japan to Hawaii and began fishing commercially for skipjack. Following the introduction of Japanese fishing methods and gear, the fishery underwent a period of rapid expansion.

The skipjack boats used by the early Japanese fishermen were of the sampan design. These boats were typically about 20 feet in over-all length, with a 4½-foot beam, and a 16-inch draft. They were usually propelled by a scull, although many of the boats were also rigged for sails. Each was fitted with an overhanging stern which housed the rudder. There was a series of wells built into the center of the boat in which live bait was carried. The wells were from 12 to 15 inches deep and fitted with screened holes along the bottom to allow sea water to enter and circulate in the wells when the boats were under way. Most of the sampans carried a fishing crew of from 4 to 6 men.

The first gasoline-powered skipjack boat in the Islands was successfully operated in 1907. Soon afterward, larger boats were designed with many new features, making it possible for practical fishing operations to be carried on at increasingly greater distances offshore. Many of the improved features which were incorporated in the development of these boats have been attributed to a Japanese fisherman named Kitayama, who was active in the fishery in the 1930's. The first flying bridge was installed in 1931, and the first pump-spray systems, which are used during fishing, were added around 1935. Beginning about 1939, the design of the hull was altered to allow more freeboard forward.

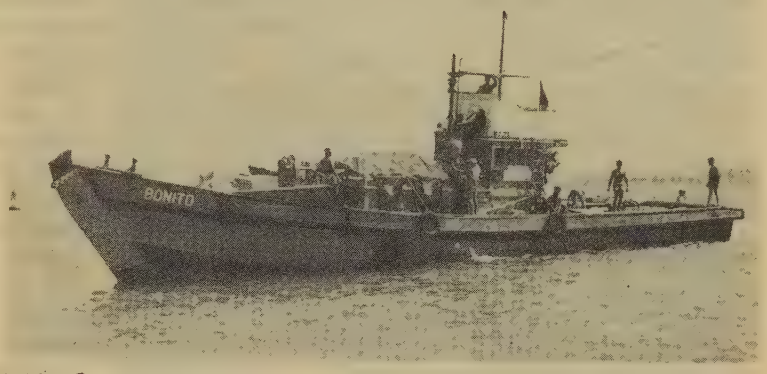

FIGURE 3 - A TYPICAL SAMPAN-TYPE FISHING BOAT USED IN THE HAWAIIAN SKIPJACK FISHERY.

The 1948 fishing fleet was comprised of 32 boats that fished exclusively for skipjack. Of these, 21 boats were based at Honolulu; 4, on the island of Maui; and 7, on the island of Hawaii. In addition to the regular fleet, there were a number of small boats that operated seasonally from various ports throughout the islands.

FISHING BOATS AND CREWS

The present-day Hawaiian skipjack boats have evolved from the Japanese sampan-type tuna boats which were introduced in these waters around 1900. Various modifications in design have given rise to a distinct type of vessel adapted to local needs and conditions. These boats have a high narrow bow, with moderate freeboard aft, and vary from 29 to 92 feet over-all (figure 2). The majority of the boats in the fleet are from 70 to 88 feet in length, with a beam of from 13 to 16 feet. They are powered by Diesel engines of either the slow-speed, heavy-duty type, ranging from 135 to 250 h.p. or of the high-speed type, ranging from 165 to 330 h.p. The general features of this type of vessel are shown in figures 3 and 4.

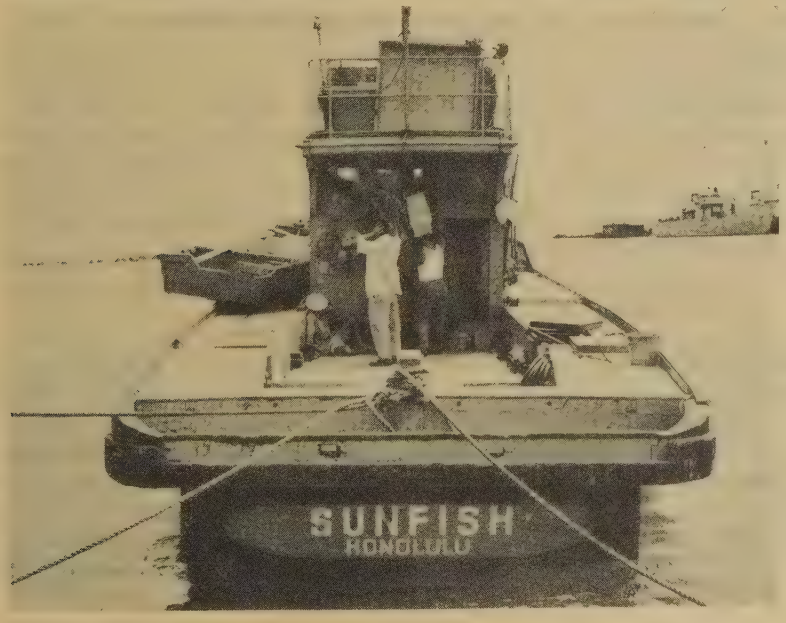

FIGURE 4 - DECK ARRANGEMENT OF A TYPICAL SKIPJACK FISHING BOAT, KEWALO BASIN, HONOLULU.

These boats are completely decked and fitted

with a pilothouse and flying bridge amidships. The engine room and a low trunk cabin are forward, with sleeping quarters for the crew provided in the forecastle and the pilothouse. The boats are equipped with radio, but only a few have adequate navigational equipment to permit long-range sea trips. There are from 2 to 6 live-bait wells fitted below the main deck abaft the engine room. Only two of the boats in the fleet are equipped with pump-circulating systems in the bait wells. On the remaining vessels, circulation is provided by a series of screened holes along the bottom of the well which allow sea water to enter when the boats are underway. If bait is carried aboard these vessels while lying at anchor in quiet water, it is necessary for the crews to rock the boats to insure proper circulation in the well; however, on boats that have pumps installed for fraining the bait wells, the pumps are used to circulate water in the wells when hove to under these conditions.

A sponson extends along both sides of the after deck and across the stern. It is from 3½ to 4 feet wide and is raised about 2 feet above deck. Storage space is provided here for food and water. The sponson usually also houses a gasoline stove, since very few of the boats have any sort of galley. The skiff is lashed along the starboard side of the raised trunk cabin.

These boats are equipped with a series of nozzles spaced at 4-foot intervals across the stern and along the after port and starboard gunwales through which sea water is pumped during fishing. It is claimed that the spray excites the skipjack into biting; in addition, the spray may also serve to screen the boat and movements of the fishermen.

Stowage for the catch is provided in the bait wells as they are emptied of bait during fishing. Since most boats operate on daily runs out of port, refrigeration is not essential. However, an ice load of about 3,000 pounds is usually carried to insure preserving the catch should a fishing trip last several days. The total carrying capacities of the boats vary from about 10 to 30 tons.

The crews of the skipjack boats are predominantly of Japanese extraction. The larger boats in the fleet maintain crews of from 9 to 13 men, while some of the smaller boats employ crews of only 3 or 4. The crew consists of a captain, an engineer, and the fishermen. Usually one of the more experienced members of the fishing crew does the chumming.

Fishing is done on a share basis. The crews are usually paid at the end of each week, after operating expenses, such as fuel, oil, and ice, have been deducted from the gross. The boat owner's share is 30 percent; the captain receives a 5 percent bonus, and the remaining 65 percent is divided equally among the crew. Food expenses for the fishing trip are usually deducted from the crew's share, with all other than the above mentioned expenses being paid by the boat owner.

FISHING GEAR

The gear used for catching skipjack consists of a bamboo pole, to which is attached a length of line bearing a hook at its end. The poles, the largest of which are from 2½ to 3 inches in diameter at the butt, vary from 7½ to 15 feet in length. The shorter poles are generally used for landing fish weighing over 20 pounds, while the longer poles are used for catching fish of smaller size. A small loop of linen is seized to the upper end of the pole, to which is fastened a 6-to 12-foot length of line. The line is fabricated by hand by twisting together 2 strands of size 40-3 or 50-3 Irish linen thread, with from 5 to 10 threads to a strand. A 12- to 16-inch

length of galvanized or piano-wire leader, which bears the hook, is attached to the lower end of the line. The leader is fastened by a short length of linen line in such a manner that it may be rapidly removed and changed during fishing. A 2-inch loop of linen line at the lower end of the leader provides for attachment of the hook.

Galvanized barbless hooks are used in various sizes to suit the size of fish taken. A plain hook is used for fishing with live bait when the skipjack will not take the more commonly used artificial jig or striker. The jig consists of a hook, the shank of which is embedded in tubular lead or brass. Various colored feathers or threads are added to make an attractive lure. A bit of dried "mahimahi" (Coryphaena hippurus) skin or a short length of quill is fastened around the base of feathers to prevent fraying. Hooks of various types are shown in figure 5.

FIGURE 5 - VARIOUS HOOKS USED IN THE HAWAIIAN SKIPJACK FISHERY. THE UPPER JIG IS AN IMPORTED JAPANESE HOOK. THE BARE HOOK AT LEFT CENTER IS USED WHEN FISHING WITH LIVE BAIT. THE REMAINING TWO JIGS ARE OF THE TYPES MOST COMMONLY USED.

BAIT

BAIT SPECIES: Live bait is essential in pole-and-line fishing for skipjack. Several different types of small fish are used, depending upon their availability. The most common bait fish in Hawaiian waters is a small anchovy, with the local name "nehu," (Engraulis purpureus Fowler). It is a small omnivorous shore fish that occurs in schools over sand and mud bottoms in most of the larger bays and inlets that fringe the coastlines. It appears to have a rather short life cycle and grows to a maximum length of about 3 inches. This species is preferred above all others by the skipjack fishermen because, in addition to its good survival qualities in the bait wells, it characteristically "schools up" close to the boat when scattered as chum. Furthermore, nehu are not overly active in the water, and for this reason, the skipjack do not strike the hooks excessively hard in response to the chum. Nehu comprise about 95 percent of the total bait catch in the Territory (table 1).

The second most important species used for live bait is a member of the silversides family, to which belongs the jack smelt and the grunion found off the Pacific Coast of the United States. This bait fish is known locally as "iao" (Atherina insularum Jordan and Evermann), and although it is not as abundant in this locality as the nehu, it is a much hardier bait and is readily taken by the skipjack. Many fishermen claim, however, that because of the larger size of the iao, it is not as suitable for bait as the nehu. Several members of the herring family (Spratelloides delicatulus Bennett, locally called "piha" and Etrumeus micropis Schlegel, called "makiawa"), when obtainable, are also utilized.

Table 1 - Live Bait Fish Catch in Boxes[1/] Taken by the Skipjack Boats, Territory of Hawaii, 1946-48

Species	Locality	1946	1947	1948
Nehu	Oahu	2,788	3,615	4,193
	Maui	1,134	908	1,899
	Hawaii	235	245	624
	Kauai	12	89	155
	Molokai	34	25	82
	Lanai	-	-	15
Other Bait Fish	All Islands	107	243	339
Totals		4,310	5,125	7,307

1/USUALLY 6 BUCKETS OF BAIT ARE PLACED IN EACH BAIT WELL WHICH IS CALLED A BOX. (A BUCKET MAY CONTAIN ANYWHERE FROM 25 TO 75 PERCENT FISH BY VOLUME. (SEE TEXT, PP. 10 AND 12)
SOURCE: BASED ON CATCH RECORDS OF THE TERRITORIAL DIVISION OF FISH AND GAME.

BAIT FISHING GROUNDS: While the above bait species are generally distributed throughout the main islands in the Hawaiian group, the relative abundance of the different species in various localities is limited by the habitats of suitable types available to them. The principal bait grounds on the island of Oahu are Kaneohe Bay, Pearl Harbor, and the Ala Wai Canal, with secondary areas located at Heeia, Waikane, and Waialua. The boats operating in the waters adjacent to the island of Hawaii obtain the bulk of their bait in Hilo Bay, Kawaihae Bay, and Kalihi. The chief bait grounds off Maui are Kehei Bay, and Maalaea Bay, while along the coast of Molokai, Kaunakakai is the only area worthy of note. Minor bait grounds also occur at Nawiliwili Bay and at Hanapepe Bay off the island of Kauai.

Kanoehe Bay is the most consistently employed baiting ground of all. Between 50 and 60 percent of the total annual nehu catch is taken from this area alone. Although seasonal fluctuations in abundance occur, both nehu and iao, as well as the other species mentioned, can be taken here throughout almost the entire year. Pearl Harbor supports considerable quantities of both nehu and iao, but baiting operations in this area have been restricted by various Naval regulations, and for this reason, it has not been visited by the skipjack boats as often as some of the other areas.

The available bait supply in the main Hawaiian islands is not greatly in excess of the needs of the present fleet, and any great increase in the number of live-bait fishing boats using these baiting grounds is not to be expected. Hence, much expansion and development of the live-bait fishery for skipjack in these waters would require that bait be obtained from other regions. Such areas as those adjacent to French Frigate Shoals and other islands in the leeward chain may prove to be substantial baiting grounds. Iao, for example, are known to occur in quantities at times in the vicinity of French Frigate Shoals (Smith and Schaefer, 1949; Eckels, 1949). Other species suitable for use as live bait have also been captured in the same area.

METHODS OF CAPTURE: Lift nets are used at night for catching nehu and piha. The nets are from 15 to 25 fathoms long and about 12 fathoms deep. The dimensions and rigging of a net of this type are shown in figure 6. This gear is operated in combination with a submarine light which is used to attract the fish as the fishing boat lies at anchor over the bait grounds. The light is attached to the end of a pole and supported about 20 feet out from the port side of the boat. To prevent the light from splashing and possibly frightening the fish as the boat rolls, the globe is hung several feet below the surface of the water. The light is turned on about dark, and it is usually left on until about an hour before daybreak when a bait haul is made. If bait is especially plentiful, the net may be set whenever

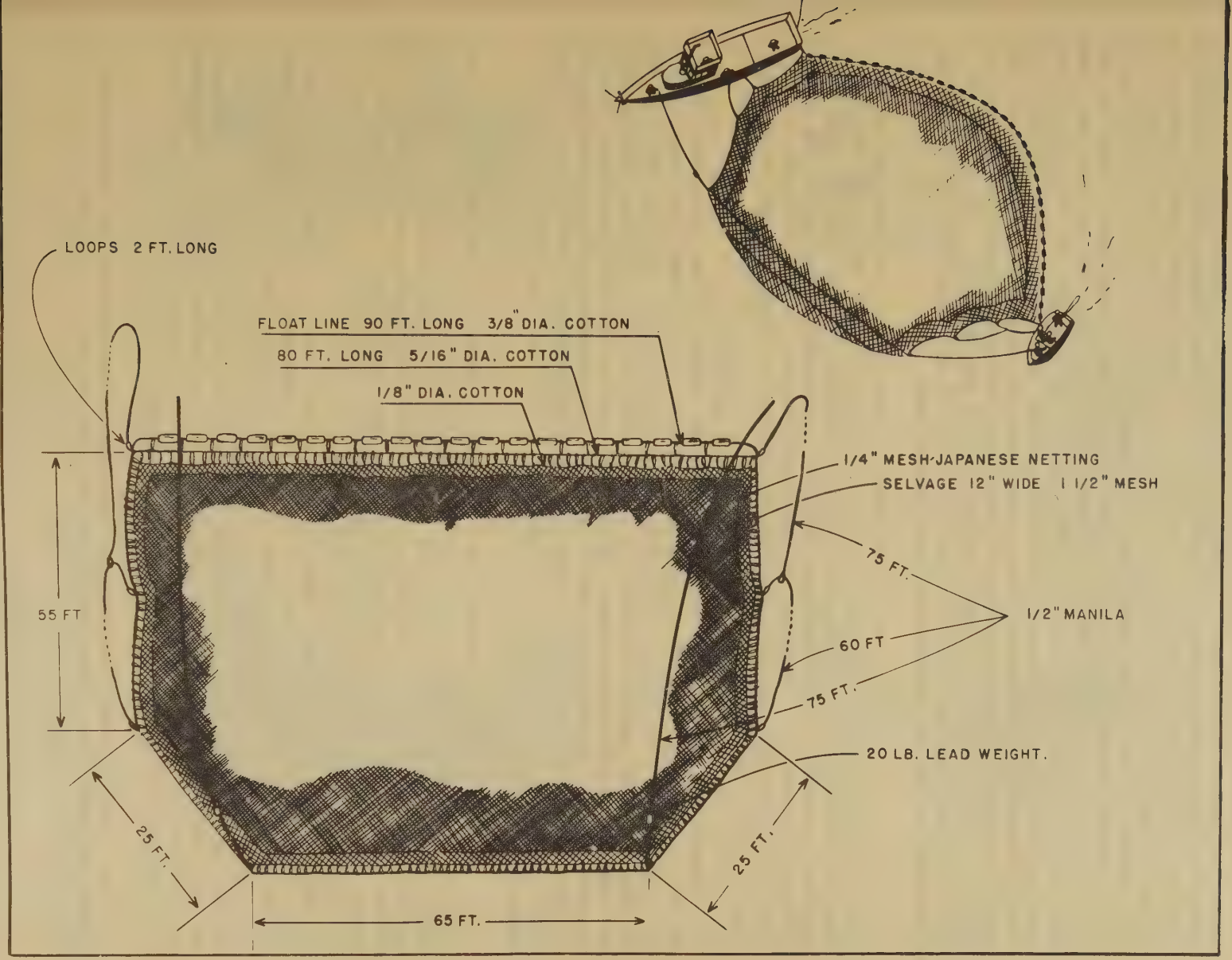

FIGURE 6 - LIFT NET USED FOR CAPTURING BAIT FOR SKIPJACK FISHING

sufficient numbers of fish have been attracted by the light. Frequently, a rheostat is used to dim the light shortly before netting operations begin. This technique causes the bait to concentrate more compactly around the light, and it also serves to screen the movement of the net in the water. In making a bait haul, the net is paid out from the net skiff. One end of the cork line is secured to the port side of the stern of the fishing boat. The crew aboard the skiff pay the net out as the skiff is moved perpendicularly to the port side of the fishing boat. When the net is completely paid out, the skiff is turned parallel to the fishing boat, and the crew aboard the skiff then pull the lead line and the rib lines as the skiff moves along the outer edge of the net. Meanwhile, aboard the fishing boat, the lead line is pulled from the bow and made fast, as are the rib lines. At a signal from the captain, the net is pulled on both the skiff and the fishing boat. As the net is "dried up," the fish are pocketed between the boat and the skiff. The light is turned out just before brailing begins, and the fish are transferred from the bag of the net to the bait wells aboard the fishing boat.

The fish are dipped out of the net with a bucket by one man standing in the skiff. Lifting the bucket from the water, he passes it to a second man standing along the gunwale of the fishing boat where it is taken by the next man standing over the bait well. The bucket with the fish is completely immersed in the water in the well before it is emptied and the fish liberated. A similar chain of men return the buckets to the man brailing from the skiff. Every precaution is taken to avoid injury to the fish.

Often the amount of bait caught during night fishing is not sufficient for the trip to sea. In this event, an attempt is made to supplement the catch with iao. This species is captured with surround nets during the daytime, since it does not respond to the artificial light at night as do the nehu and piha. The surround nets used for capturing "day bait" differ considerably from the night nets, both in construction and in operation. While there are many variations in the dimensions of these nets, they are generally about 80 fathoms long and 4 fathoms deep, with a fairly deep bunt. The details and dimensions of a net of this type are shown in figure 7.

A net skiff with an outboard motor attached is generally used for setting the surround net in waters over 1 or 2 fathoms deep. When a school of bait fish has been located, the net is paid out from the skiff as the skiff encircles the school. When the set is completed, the two ends of the net are pulled aboard the skiff. One of the fishermen holds the junction of the two ends of the lead line together to prevent the fish from escaping alongside the skiff, while five or six fishermen, wearing goggles, dive down and work the lead line over the bottom and thus keep the net from becoming snagged. When the net is sufficiently "dried up," the bait is brailed from the pocket of the net into a bait compartment built in the center of the skiff. The skiff then proceeds to the fishing boat where the bait is transferred to the bait wells. In the event that bait is caught close to the anchored fishing boat, the net with the captured fish is towed directly to the boat where the fish are brailed from the net into the wells. Since many of the baiting areas are over shallow coral-studded bottoms, it is often necessary for the fishing boat to anchor at a considerable distance from the scene of baiting operations.

When fishing in shallow waters close inshore, the surround net is operated in the same manner as a beach seine, and the captured bait is transported to the fishing boat by means of the bait skiff.

Bait is measured by the "bucket." The number and weight of fish per bucket varies considerably due to differences in bucket sizes and the concentration of

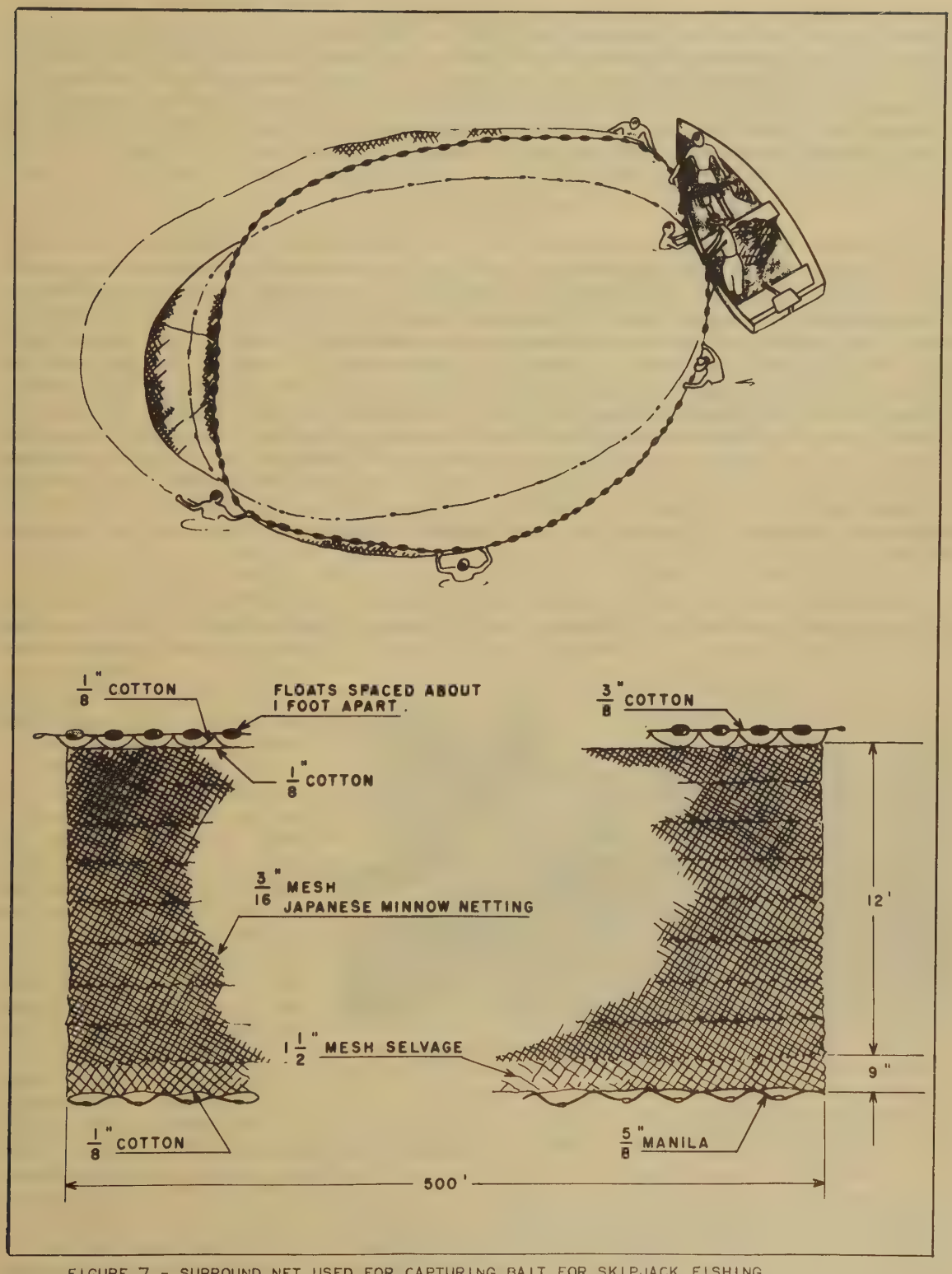

FIGURE 7 - SURROUND NET USED FOR CAPTURING BAIT FOR SKIPJACK FISHING.

bait in the net at the time of brailing. A bucket may contain anywhere from 25 to 75 percent fish by volume; hence any estimate of the amount of bait taken by the skipjack fleet is but a rough measure of the catch. Usually 6 buckets of bait are placed in each bait well which is called a "box." Since the size of the bait wells and the circulation therein vary considerably from boat to boat, the bait capacity of the wells, therefore, show considerable variation, so anywhere from 4 to 8 buckets may be a "box" depending on the particular vessel.

FISHING METHODS

Since the skipjack is a schooling fish, its presence may be detected in several ways. Schools may be encountered where the fish are finning or jumping at the surface. Breezing schools, which give the appearance of wind disturbance or a tide rip on the surface, are seldom seen in this area because of prevailing rough sea conditions. The presence of a school is most often revealed by flocks of sea birds "working" above the fish. Generally speaking, large numbers of birds flying low over the surface of the water and continually diving as if feeding are an indication of fish. An experienced skipjack fisherman is able to distinguish by the activity of the birds whether a school of fish is worth any fishing effort. Moreover, once having located a school, he can usually anticipate the movements and behavior of the fish. The sea birds for which the Hawaiian fishermen are ever on the look out include frigate birds, the Hawaiian and noddy terns, and gannets. In these waters skipjack are very seldom encountered together with schools of porpoise as is common off the coast of Central America.

The Hawaiian technique of fishing for skipjack is somewhat different from that employed by the American and Japanese tuna fishermen. When a school of fish has been located, the boat circles the fish in an attempt to cross in front of the school. As the boat approaches the school, the engine is throttled down, and the captain takes up a position in the stern of the boat, where he maneuvers the boat by means of a tiller. Simultaneously, the spray apparatus is turned on and the chummer begins throwing bait overboard. Using a small dip net, he scatters the chum over the surface of the water a few fish at a time. If the fish are biting and rush in to take the chum, bait is thrown m more rapidly in an effort to bring the skipjack up close to the stern of the boat. The fishermen take their fishing positions and move the jigs across the surface in short arcs to simulate living fish. The older and more experienced fishermen station themselves along the stern where fishing is usually best, while younger members of the crew take positions along the gunwales (figure 8). Suddenly the first fish strikes. Each fisherman braces himself for the onrush of fish. The base of the pole rests against a denim pad hung in front of the groin. The left hand grips the pole and the right hand is free. When a fish strikes, the right hand quickly grasps

FIGURE 8 - SKIPJACK FISHING. A SCHOOL OF FISH HAS BEEN "CHUMMED" CLOSE TO THE BOAT AND THE FISH ARE JUST COMMENCING TO BITE.

the base of the pole, and the fisherman leans back and down, utilizing the initial speed of the fish to lift it out of the water and swing it toward the boat. As the fish hurtles through the air, the fisherman catches it under his left arm, and with the pole supported across his right forearm, he removes the hook with his right hand and drops the fish on deck behind him as the jig goes back into the water ready for the next fish. The practice of catching a fish under the arm is a matter of necessity with the local fishermen, since the limited amount of deck space on the sampans prevent flipping the hooked fish aboard. This technique demands the utmost skill and agility on the part of the fisherman, especially when fish are large and there is a heavy sea running.

The fishermen may often change poles during fishing. Generally, the short heavier poles are used when the fishing first begins and the fish are biting continuously, but as the fishing slackens or the larger fish lag behind, the fishermen switch to the longer poles and use the most attractive jigs in their repertory. Because of the difficulty of landing large fish when the long poles are used, the less experienced fishermen gaff the fish for those doing the fishing. The technique by which two or more poles are attached to a single hook is never practiced by the local fishermen; however, the fishermen often assist one another in landing large fish by using the tips of the poles to support the pole bearing a hooked fish.

The actual fishing time is usually of relatively short duration. The schools encountered in these waters will stay with the boat for a period varying from a few minutes to half an hour. If the fish suddenly stop biting, and the school is large, a second run may be made on the school; however, if the fish will not bite on the second attempt, the school is usually abandoned. Oftentimes, the schools encountered will not respond to the chum, or the fish may take the live bait readily but will not touch a hook. At such times, the boat moves on in search of another school.

When the last fish has been brought aboard, the catch is stowed in one of the empty bait wells. The deck is scrubbed down, and the boat sets off in search of another school.

FISHING AREAS AND SEASONS

The operations of the Hawaiian skipjack fleet are largely confined to the waters immediately adjacent to the main islands. In the past, lack of proper navigational equipment and adequate refrigeration has limited the extension of the fishery into the more distant offshore waters. It has been only during the 1949 season that several of the boats installed radio direction finders which permitted them to venture farther offshore. Most of the fishing is centered around the island of Oahu, since the bulk of the fleet is based at Honolulu. Moreover, the presence of fish in the surrounding waters and the proximity of the main baiting grounds permit many of the boats to operate on single-day runs out of port. Some of the larger Honolulu boats, however, range as far eastward as the island of Hawaii and as far westward as Kauai and Niihau. The more distant trips usually last from 2 to 3 days, depending on fishing success. Hilo boats generally confine fishing operations to the windward side of Hawaii, while Kawaihae boats fish along the leeward coast. Maui boats generally fish in the waters adjacent to Molokai, Maui, and Lanai. The main fishing grounds are shown in figure 9.

Weather conditions and information obtained from other boats often influence the fishermen's choice of a particular fishing area. Skipjack are not found in uniform abundance throughout the waters surrounding the main islands, consequently, considerable time on occasions may be spent in searching for schools of fish. Most of the boats fish throughout the year except for periodic maintenance lay-ups. The winter

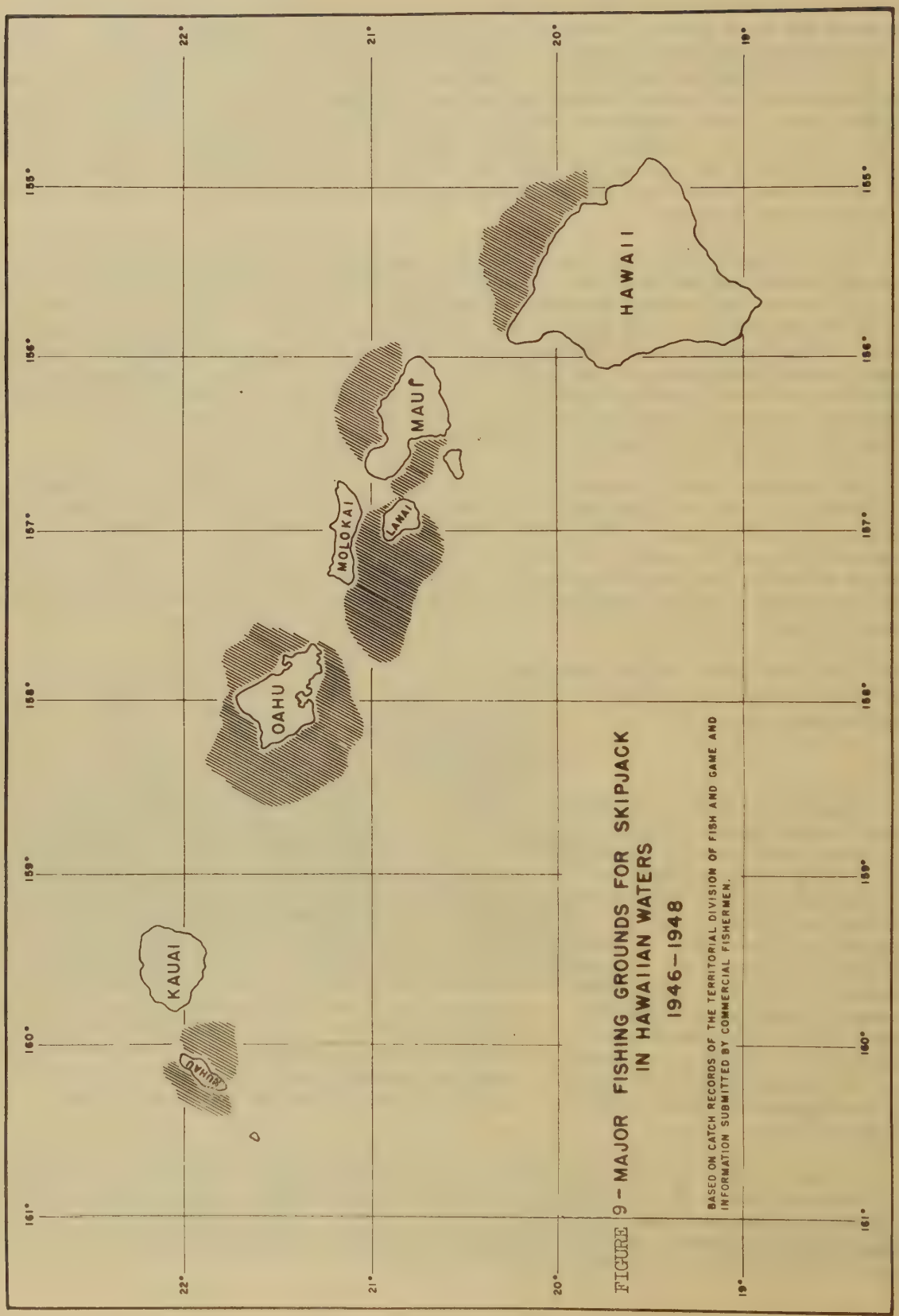

FIGURE 9 - MAJOR FISHING GROUNDS FOR SKIPJACK IN HAWAIIAN WATERS 1946-1948

BASED ON CATCH RECORDS OF THE TERRITORIAL DIVISION OF FISH AND GAME AND INFORMATION SUBMITTED BY COMMERCIAL FISHERMEN.

season is slack, however, as compared with the summer fishery. Unfavorable weather conditions often make it necessary for the fleet to suspend fishing operations during this period, especially during the month of December. Furthermore, during the winter the fish are less abundant in Hawaiian waters, and the schools are reportedly smaller than those encountered in the summer fishery. The first appearance of the fish marking the beginning of the summer season usually occurs in May. After increasing rapidly to a maximum in June or July, the catches drop off gradually (See figure 10). Figure 11 illustrates the season of peak catch, with average monthly catches expressed as percentages of the average annual catches for the three-year period ending with 1948.

DISPOSITION OF THE CATCH

Since many of the skipjack boats operate on short runs out of port, the fish are oftentimes landed at the dock within a few hours after they have been caught (figure 12). The chief port of landing for the skipjack fleet is Honolulu. During the summer season, the bulk of the catch is sold to Hawaiian Tuna Packers Ltd. for canning. The plant is located close to the dock where the fish are unloaded and transferred by trucks to the cannery to await processing (figure 13). In addition to the main packing plant, the cannery also maintains a small subsidiary at Hilo where fish are received for shipment to the plant in Honolulu. The price paid to the fishermen by the cannery for the fish is based on the prevailing price of skipjack on the Pacific coast, less a differential approximating shipping costs.

Only a few of the Honolulu boats sell their catches exclusively to fresh market outlets; however, during the winter months the skipjack landings are not sufficient to keep the cannery in operation, and the fish are then handled by the fresh markets. On most of the other islands, the entire catch is absorbed by the fresh market. The prices received by the fishermen for skipjack going to the fresh market fluctuates with the supply; generally, however, the average market price is slightly above the prevailing price paid by the cannery.

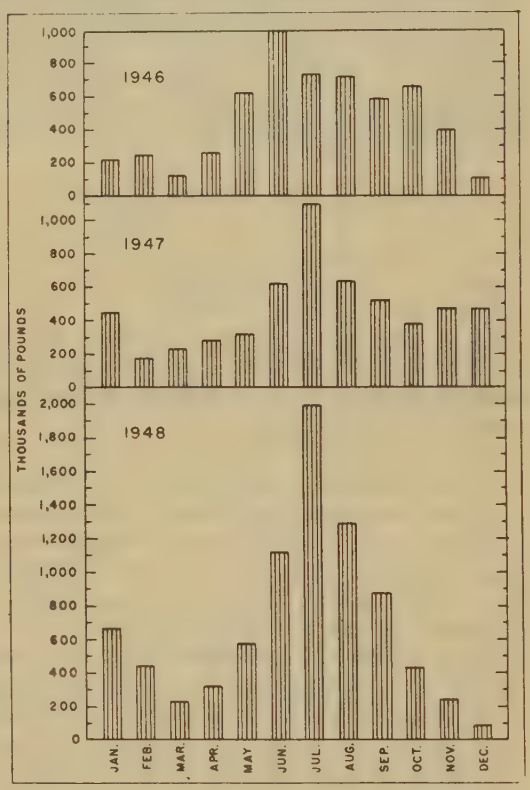

FIGURE 10 - SKIPJACK LANDINGS BY MONTHS IN THE TERRITORY OF HAWAII, 1946-48. (DATA OBTAINED FROM THE CATCH RECORDS OF THE TERRITORIAL DIVISION OF FISH AND GAME.)

FUTURE POSSIBILITIES FOR THE DEVELOPMENT OF THE FISHERY

There seem to exist excellent possibilities for expansion of the skipjack fishery based on the Hawaiian Islands. Intensive research is underway, both by the U. S. Fish and Wildlife Service Pacific Oceanic Fishery Investigations and other agencies, for exploring and developing the tuna resources of the Central Pacific. Data are presently being gathered for studies of the basic biology of the skipjack. In addition, exploratory and experimental fishing is also being conducted with the aims of locating potentially productive areas, developing new gear, and improving existing methods and techniques for catching fish. Concomitant with this work, oceanographi-

cal surveys are being carried on to correlate with the exploratory findings. The results of such research eventually should lead to a more efficient exploitation of local tuna resources and an extension of the fishery into adjacent geographical regions. The Line Islands and the expanse of islands and shallow-water banks extending northwestward from Niihau perhaps offer the most promising potential fishing grounds for immediate expansion.

As mentioned previously, the existing bait supply in the Hawaiian Islands is limited. Studies are now in progress to determine the factors in the physiology of the bait species related to handling and transporting them more effectively. Investigations with regard to the condition of the local bait fishery for nehu are being conducted by the University of Hawaii and the Territorial Division of Fish and Game for the purpose of determining the maximum yield that can be harvested without causing a serious decrease in the local populations. Hope for future expansion also lies in the further extension of bait fishing in areas which have not been fished intensively in recent years, such as Pearl Harbor and others previously noted. There are also several areas lying to the northwest of the main island group which have not as yet been extensively exploitated commercially and which offer possibilities for an increased bait supply.

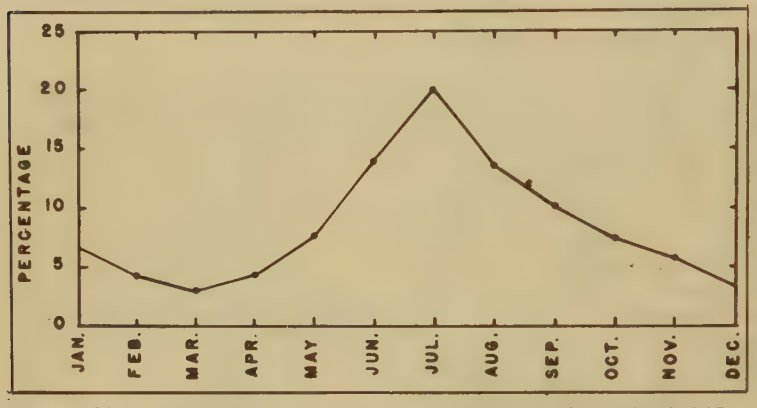

FIGURE 11 - LANDINGS OF SKIPJACK IN MONTHLY PERCENTAGES FOR THE 3-YEAR PERIOD ENDING 1948.

The local fishing fleet is continually incorporating modern mechanical equipment and methods which enable the vessels to venture farther offshore to exploit oceanic fish stocks which otherwise might not be available to the fishery. The installation of pump-circulation systems in the bait wells of several of the boats minimize the bait requirements (through reduced mortality rates of bait carried in the wells) and thus lead to an increase in profitable fishing time, and also allow larger loads of bait to be carried. Radio direction finders are becoming standard equipment on an increasing number of boats. Hence, such vessels are no longer limited to coastal waters because of inadequate navigational aids. However, other modifications on the present boats would be necessary before their cruising range could be economically increased to any great extent. For instance, modern refrigeration adequate for holding a catch during extended fishing trips would have to be provided. Further improvement of living accommodations aboard the boats would provide greater comfort to the fishermen at sea.

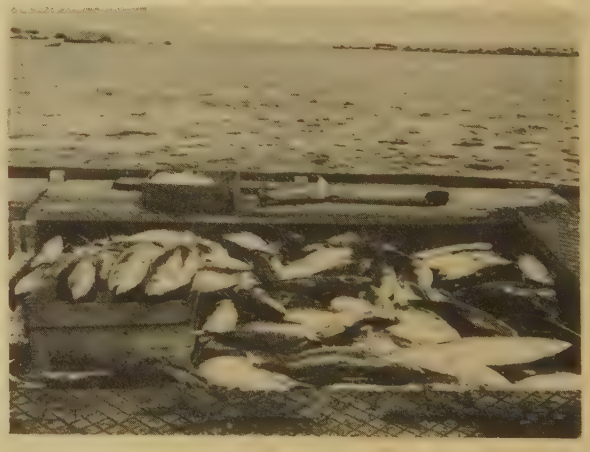
FIGURE 12 - A SKIPJACK CATCH WAITING TO BE UNLOADED AT KEWALO BASIN, HONOLULU.

There are other considerations which must not be overlooked and which directly affect the development of the fishery. First, should there be a substantial increase in production, adequate facilities for handling the catch must be provided. The demands of the fresh market constitute only a small portion of the total annual skipjack landings, therefore, the greater part of the catch must be processed. In this respect, plans for another tuna canning plant to be located on the island of Kauai have already been formulated, and it is planned that it will be in operation by 1951. Second, there is at present a shortage of fishermen well trained in local fishing methods, hence, an increased demand for experienced personnel to man additional fishing boats would be even more critical unless additional fishermen could be trained, or the fishing methods were sufficiently modified to attract experienced fishermen from the U. S. mainland. Third, it is likely that problems would arise with regard to financing any new fishery enterprises. For example, financing the ownership and operation of a vessel by an individual or group is often difficult without substantial backing from an outside source.

FIGURE 13 - SKIPJACK BEING UNLOADED FROM A SAMPAN FOR TRANSFER TO THE CANNERY, KEWALO BASIN, HONOLULU.

There are, of course, many other factors than those mentioned above to be considered that will effect the future development of the fishery. It may be pointed out, however, that the general feeling among local interests is that the fishing industry, and particularly the skipjack fishery, offers opportunities for the Territory under favorable marketing conditions on the mainland where the major part of the Hawaiian tuna pack must be sold.

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NOTES

Two Juvenile Pointed-tailed Ocean Sunfish, *Masturus lanceolatus*, from Hawaiian Waters

JOSEPH E. KING[1]

The pointed-tailed ocean sunfish, *Masturus lanceolatus* (Liénard), is one of the "rare" marine fishes although it has been recorded from the tropical and subtropical areas of all oceans. In Gudger's review (1937*b*) of the natural history and distribution of the species, he reported only 59 authenticated records of the fish in the hundred years after its discovery in 1836. Strangely enough, of these 59 individuals there were 28 young and 31 adults, with no examples between the largest small specimen (60 mm. or 2.4 inches, standard length) and the smallest large specimen (30.5 inches, total length). Brimley (1939) has supplied records of five adult fish, ranging in size from 28 to 83 inches, that were not included in Gudger's report; four of these fish were from North Carolina waters, the fifth from Florida.

This wide gap between larval fish and adults was partially filled when three 6-inch juvenile fish were obtained from the stomach of a dolphin, *Coryphaena hippurus* L., taken in Florida waters (Gudger, 1938). Kuronuma (1940) described a juvenile *M. lanceolatus*, taken in a gill net in Japanese waters, which was 145 mm. in length from snout to caudal base and 259 mm. from snout to end of caudal fin. This interesting specimen differed from any previously described in that the caudal lobes was extended as a thin filament equal to approximately half the total body length.

Recently, Fitch (1950) reported that *M. lanceolatus* is found quite commonly in the stomachs of yellowfin tuna taken in Hawaiian waters, nearly a hundred specimens varying in size from ¼ inch to 2 inches having been obtained from this source. The only previous record of the species for Hawaiian waters is that of an adult fish, 37.3 inches in length, obtained from the Honolulu fish market in 1919 (Fowler, 1928).

The author has been unable to find in the literature any reports, except that of Kuronuma (1940), which describe or figure the caudal fin of *M. lanceolatus* as having more than a short lobe-like extension which may be pointed in the very young but in the adults is usually frayed or mutilated. From this characteristic shape of the caudal fin the fish has derived its scientific name, *Masturus lanceolatus* [Gr., *mastos*, breast or nipple; Gr., *oura*, tail; L., *lanceolatus*, a little lance = the nipple-tailed, lance-tailed fish (Gudger, 1937*a*)].

On April 11, 1950, during long-line fishing for tuna by the Fish and Wildlife Service research vessel *Hugh M. Smith*, a dolphin (1,100 mm. fork length) was taken just west of the island of Hawaii at 19° 30′ N. Lat.–156° 05′ W. Long. In the dolphin's stomach were two 5-inch *M. lanceolatus*, one in good condition, the other with a gash on each side. Both specimens (in alcohol) are generally similar in coloration to the 6-inch fish described by Gudger (1938). They are dark gray dorsally, shading into milky-white on the lower two-thirds of the body. They have the typical gray spotting below the eyes and pectoral fins and posteriorly above the anal fin.

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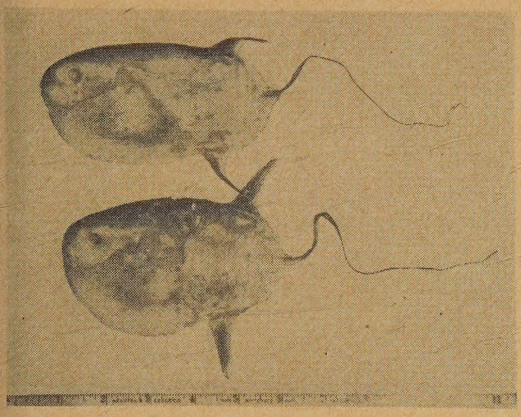

FIG. 1. Two juvenile *Masturus lanceolatus* taken from the stomach of a dolphin captured in Hawaiian waters. April 11, 1950.

These fish differ in one important respect, however, from any previously collected. Each has the caudal lobe continued as a whip-like structure longer than the body of the fish (Fig. 1). Except for the proximal 2 or 3 centimeters, this caudal extension is very fragile, almost paper-thin, and is frayed toward the tip. These may be the first observed specimens—at least among the post-larvae, juveniles, and adults—to show the true "normal" or unmutilated nature of the caudal fin. In view of the delicate structure of this appendage it is easily seen why the appendage is usually greatly reduced or missing in juvenile and adult specimens.

Measurements of the two fish, fin ray counts, etc., are given in the accompanying table:

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TABLE 1

MEASUREMENTS AND FIN-RAY COUNTS OF TWO JUVENILE POINTED-TAILED OCEAN SUNFISH (LENGTH AND DEPTH IN MILLIMETERS)

SPECIMEN	LENGTH TO			DEPTH			FIN-RAY COUNT				
	Base C	Edge C	Tip C	Behind eye	Before D & A	Over D & A	P	D	C	A	D+C+A
Good condition	111.9	135.0	300	59.8	63.6	121	10	20 (19?)	5+6+8	19 (18?)	58
Gashes in both sides	107.2	129.0	317	68.2	68.6	135	10	19 (18?)	5+6+7	18	55